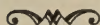


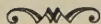
Transactions

of the

American Fisheries Society



EIGHTY-THIRD ANNUAL MEETING
MILWAUKEE, WISCONSIN
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¹ Correspondence should be addressed to E. B. Speaker, Iowa State Conservation Commission, Des Moines, Iowa. Mr. Speaker was elected Secretary-Treasurer at the Eighty-third Annual Meeting.

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³ At time of the Eighty-third Annual Meeting.

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PRESIDENTS' TERMS OF SERVICE AND PLACES OF MEETING

The first meeting of the Society occurred December 20, 1870. The organization then effected continued until February, 1872, when the second meeting was held. Since that time there has been a meeting each year, as shown below. The respective presidents were elected at the meeting, at the place, and for a period shown opposite their names, but they presided at the subsequent meeting.

1. William Clift	1870-1872	New York, N. Y.
2. William Clift	1872-1873	Albany, N. Y.
3. William Clift	1873-1874	New York, N. Y.
4. Robert B. Roosevelt	1874-1875	New York, N. Y.
5. Robert B. Roosevelt	1875-1876	New York, N. Y.
6. Robert B. Roosevelt	1876-1877 ¹	New York, N. Y.
7. Robert B. Roosevelt	1877-1878	New York, N. Y.
8. Robert B. Roosevelt	1878-1879	New York, N. Y.
9. Robert B. Roosevelt	1879-1880	New York, N. Y.
10. Robert B. Roosevelt	1880-1881	New York, N. Y.
11. Robert B. Roosevelt	1881-1882	New York, N. Y.
12. George Shepard Page	1882-1883	New York, N. Y.
13. James Benkard	1883-1884	New York, N. Y.
14. Theodore Lyman	1884-1885	Washington, D. C.
15. Marshall McDonald	1885-1886	Washington, D. C.
16. W. M. Hudson	1886-1887	Chicago, Ill.
17. William L. May	1887-1888	Washington, D. C.
18. John Bissell	1888-1889	Detroit, Mich.
19. Eugene G. Blackford	1889-1890	Philadelphia, Pa.
20. Eugene G. Blackford	1890-1891	Put-in-Bay, Ohio
21. James A. Henshall	1891-1892	Washington, D. C.
22. Herschel Whitaker	1892-1893	New York, N. Y.
23. Henry C. Ford	1893-1894	Chicago, Ill.
24. William L. May	1894-1895	Philadelphia, Pa.
25. L. D. Huntington	1895-1896	New York, N. Y.
26. Herschel Whitaker	1896-1897	New York, N. Y.
27. William L. May	1897-1898	Detroit, Mich.
28. George F. Peabody	1898-1899	Omaha, Neb.
29. John W. Titcomb	1899-1900	Niagara Falls, N. Y.
30. F. B. Dickerson	1900-1901	Woods Hole, Mass.
31. E. E. Bryant	1901-1902	Milwaukee, Wis.
32. George M. Bowers	1902-1903	Put-in-Bay, Ohio
33. Frank N. Clark	1903-1904	Woods Hole, Mass.
34. Henry T. Root	1904-1905	Atlantic City, N. J.
35. C. D. Joslyn	1905-1906	White Sulphur Springs, W. Va.
36. E. A. Birge	1906-1907	Grand Rapids, Mich.
37. Hugh M. Smith	1907-1908	Erie, Pa.
38. Tarleton H. Bean	1908-1909	Washington, D. C.
39. Seymour Bower	1909-1910	Toledo, Ohio
40. William E. Meehan	1910-1911	New York, N. Y.
41. S. F. Fullerton	1911-1912	St. Louis, Mo.

¹ A special meeting was held at the Centennial Grounds, Philadelphia, Pa., October 6 and 7, 1876.

42. Charles H. Townsend	1912-1913	Denver, Colo.
43. Henry B. Ward	1913-1914	Boston, Mass.
44. Daniel B. Fearing	1914-1915	Washington, D. C.
45. Jacob Reighard	1915-1916	San Francisco, Calif.
46. George W. Field	1916-1917	New Orleans, La.
47. Henry O'Malley	1917-1918	St. Paul, Minn.
48. M. L. Alexander	1918-1919	New York, N. Y.
49. Carlos Avery	1919-1920	Louisville, Ky.
50. Nathan R. Buller	1920-1921	Ottawa, Ont.
51. William E. Barber	1921-1922	Allentown, Pa.
52. Glen C. Leach	1922-1923	Madison, Wis.
53. George C. Embody	1923-1924	St. Louis, Mo.
54. Eben W. Cobb	1924-1925	Quebec, P. Q.
55. Charles O. Hayford	1925-1926	Denver, Colo.
56. John W. Titcomb	1926-1927	Mobile, Ala.
57. Emmeline Moore	1927-1928	Hartford, Conn.
58. C. F. Culler	1928-1929	Seattle, Wash.
59. David L. Belding	1929-1930	Minneapolis, Minn.
60. E. Lee LeCompte	1930-1931	Toronto, Ont.
61. James A. Rodd	1931-1932	Hot Springs, Ark.
62. H. S. Davis	1932-1933	Baltimore, Md.
63. Fred A. Westerman	1933-1934	Columbus, Ohio
64. E. L. Wickliff	1934-1935	Montreal, P. Q.
65. Frank T. Bell	1935-1936	Tulsa, Okla.
66. A. G. Huntsman	1936-1937	Grand Rapids, Mich.
67. I. T. Quinn	1937-1938	Mexico City, Mexico
68. Fred J. Foster	1938-1939	Asheville, N. C.
69. T. H. Langlois	1939-1940	San Francisco, Calif.
70. James Brown	1940-1941	Toronto, Ont.
71. John Van Oosten	1941-1942	St. Louis, Mo.
72. John Van Oosten	1942-1943	(No meeting) ²
73. John Van Oosten	1943-1944	(No meeting) ³
74. John Van Oosten	1944-1945	(No meeting) ³
75. John Van Oosten	1945-1946	(No meeting) ³
76. Joseph R. Hogan	1946-1947	St. Paul, Minn.
77. H. H. MacKay	1947-1948	Denver, Colo.
78. Seth Gordon	1948-1949	Atlantic City, N. J.
79. Milton C. James	1949-1950	Winnipeg, Man.
80. Albert S. Hazzard	1950-1951	Memphis, Tenn.
81. W. J. K. Harkness	1951-1952	Rochester, N. Y.
82. Ralph Hile	1952-1953	Dallas, Texas
83. Fred A. Thompson	1953-1954	Milwaukee, Wis.

² The annual meeting scheduled to be held in New Orleans, La., was cancelled because of the war emergency.

³ No annual meeting scheduled because of the war.

In Memoriam



Matt Patterson, Sturgeon Bay, Wis.

William Piel, Salisbury, Connecticut

George F. Stack, Cresco, Pennsylvania

Delbert L. Taber, Fort Lauderdale, Fla.



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Part 1
Papers

POLICIES AND PROCEDURES OF THE U. S. FISH AND WILDLIFE SERVICE ¹

JOHN L. FARLEY

*U. S. Department of the Interior, Fish and Wildlife Service
Washington, D.C.*

I am very happy to be with you today in this beautiful, clean, and progressive city, and in this State which was my home. In Pierce County, as a small boy, I first learned the ways of the brook trout when it was possible to "run down to the creek" and catch a mess of trout before breakfast. In this State I received my college and university training and my first job. Here I found a native daughter who has continuously helped me for many years and whose parents still live in Jackson County, having recently celebrated their 63rd wedding anniversary.

I believe that it was 25 years ago that I attended my first meeting of the American Fisheries Society. I was impressed then, and have continued to be impressed with the high quality of the discussions and the sincerity and ability of the members, so I am proud to be with you and to be one of you.

Secretary McKay of the Interior Department has asked me to convey to you his greetings and best wishes. He particularly wished me to tell you of his interest in and concern over the problems which challenge the fishery workers and his hope that through knowledge, sympathetic understanding, and sound fishery management, our great fishery resources can be maintained for food and recreation.

It was with a great deal of regret that upon the heels of my appointment as Director of the Fish and Wildlife Service, I learned that Dr. John L. Kask, Assistant Director of the Service, a distinguished scientist and widely known fisheries expert, had accepted a very attractive position in Canada. It was a distinct loss to our Service and created a vacancy which is hard to fill. This delay in filling the vacancy is unfortunate and has caused some speculation concerning the attitude of the new administration on fishery problems. I am happy to inform you that my instructions are to strengthen, as far as possible, that field of the Service's work. We are very anxious to correct the feeling that has existed in some places that the fisheries work has occupied a secondary role since the consolidation of the Bureau of Fisheries with the Bureau of Biological Survey.

I wish to consider with you some of the circumstances which, so far as I can see, will have a profound effect upon conservation policies in the United States during the next few years. I refer, of course, to the unmistakable trend toward the reduction of costs of Government, and how

¹ Address by John L. Farley, Director, Fish and Wildlife Service, at Eighty-third Annual Meeting of American Fisheries Society, Milwaukee, Wisconsin, September 17, 1953.

this trend will affect the Federal and State fishery services. The days of spending this Nation into greater prosperity and deeper debt are gone.

There are several ways to economize. We can stop buying things or doing things that cost money. We can stretch our available funds by more efficient operations, or we can make more of cooperative enterprises which require smaller individual outlays. Probably all of these methods will be used by the Fish and Wildlife Service, but it is the last method which seems to me to hold the greatest promise and is the one I wish to explore with you.

Cooperation is the very basis of organized society. Cooperation is an essential principle of our Federal form of government. I mention these commonplace facts merely to emphasize that during this period of retrenchment, closer cooperation in the field of fishery conservation and development is more essential to success than ever before.

The Constitution delegates certain powers to the Federal Government and reserves all others "to the States and to the People." Thus, ownership and management of fish and game within our borders is the clear prerogative of the individual States. The "general welfare" clause of the Preamble of the Constitution, however, grants many vague powers and responsibilities to the Federal Government, and it is the lack of definition and the omission of boundaries of functions concerned with the general welfare of the people which give rise to a long history dispute between State and Federal agencies. The maintenance of the supply of our aquatic food resources through good conservation practices is a problem of National concern and its solution very definitely in the public interest. At the same time it is a problem of local concern because the fishes in territorial waters are owned by the States and the regulation of the fisheries, which is the usual approach to conservation, is the sole prerogative of State governments.

Thus, fishery conservation is by its very nature a cooperative venture in which Federal and State governments are united. We learned long ago that conservation action is effective only when it is based on scientific knowledge. To develop this knowledge, the Federal Government has carried on a program of scientific research about the aquatic resources ever since the inception of its fishery service in 1871; and many of the States also carry on programs of fishery research. Yet there is little overlapping between these two divisions of government, for whereas the States generally deal with rather local problems—there are some exceptions—the Federal Government deals with problems of broader scope—those of interstate or international concern, or those involving principles of wide application.

Perhaps the most striking example of direct cooperation between the States and the Federal Government is the program of Federal Aid in Fish Restoration. This program is being administered by the Fish and Wildlife Service to give strength and effectiveness to this philosophy of cooperation, to the end that the program will make the greatest possible contributions to the improvement of sport fishing.

As the action agencies who must select, plan, and carry out fish restoration projects, the State fish and game departments have a great responsibility for insuring success. The Fish and Wildlife Service has and will assist the States in any way it can so maximum benefits will flow to the angling public.

The pronounced increase in the amount of Dingell-Johnson funds available this year—72 percent over last year for the Nation as a whole—may place a heavy burden on qualified manpower and will require careful planning if the money is to be utilized to greatest advantage. The record of the first two years of this program is proof of capacity of the States to put the funds to excellent use, as well as the fact that the added income was badly needed. Out of the two and a half million dollars apportioned the first year, only \$4,739, for a single State, was allowed to revert to the Fish and Wildlife Service through inability to obligate.

It is notable that so many States worked on projects designed to expand our knowledge of our sport fisheries, so management of the resource can be improved. Over half of all projects approved to date deal with the investigation of some sport fisheries problem.

Projects of a practical nature, characterized by the application of proven methods of fish restoration, are on the increase. Creation of new public fishing waters by the construction of dams, improvement of the stream environment, control of noxious vegetation, and the chemical rehabilitation of lakes, are a few of the more important types of work which will produce early, tangible benefits.

Many States have purchased lands for lake construction to insure free public access to fishing waters, or to establish control over critical areas such as spawning grounds.

The Federal Aid program is supported by funds derived from an excise tax. Taxes in general are unpopular. The tackle-buying sportsman must remain convinced that this program is paying off in terms of more and better fishing. We have a joint obligation in this regard.

A somewhat different pattern of cooperation between this Service, other Federal agencies, and the States, in which the various agencies assume differing degrees of responsibility, is exemplified by the Pacific Coast Salmon Project.

The most serious threat to the maintenance of Pacific Coast salmon is the construction of major dams, particularly on the Columbia River watershed. The States of Washington and Oregon joined with the Fish and Wildlife Service and the Corps of Engineers in 1949 in a comprehensive program for the rehabilitation and development of all possible tributary streams below the site of McNary Dam. This program included the clearance from these streams all obstructions to salmon passage, the laddering of impassable falls and small dams, the construction of hatcheries to develop more rapidly the lower river salmon populations, the screening of irrigation and power diversions to preserve the downstream migrating fingerling salmon, and a number of other associated activities. A crucial function of the States in the salmon maintenance program, and one in

which they alone can function, is the judicious regulation of the commercial fishery.

If the Congress provides the required funds in future years as programmed, it is anticipated that the greatest possible use of the lower river for salmon production will be attained within about ten years after completion of all material facilities.

In all water-use projects of the Pacific Northwest, it is important that fish ladders and screening devices be provided to protect and maintain the trout and salmon populations. Large fish screens have been provided and are maintained by the Service in Federal irrigation diversions, and a parallel program of constructing screens in smaller district and privately owned irrigation works has been prosecuted by the states for a number of years.

Another very effective form of cooperation between the States and the Service is a form of division of labor; that is, the performance of a single job, but at different places or times or by producing a different product so that the effort is integrated to avoid duplication or waste. I refer to the fish-cultural operations which this Society was organized to encourage.

The Service fish hatcheries produce and distribute salmon, trout, and warm-water species. Cooperative agreements are in effect with almost all of the States to prevent duplication of stocking and to assure that the fish will be stocked in accordance with the policies of the various States. The enormous increase in fishing since World War II has resulted in an increase of pressure on the States and the Federal Service to produce and distribute more fish. The Service is endeavoring to assign its hatchery fish to areas of greatest need and thus supplement the operations of the States. The salmon production in the West Coast hatcheries is needed to help mitigate the loss of natural runs resulting from the construction of Federal multipurpose dams. The fingerling production of trout is being curtailed in favor of the legal size which seems to be the general trend in many States. The requests for bass and sunfish for farm ponds represent about 80 percent of the total of 50,000 applications received annually. The Service will continue to review its operation so that the greatest possible returns will result from the fish-stocking program.

There is still another type of cooperation in which assistance of this Service is requested to expand projects of research and development initiated by State agencies. Examples of such cooperative projects may be found in the sea lamprey control program in the Great Lakes, which started in Michigan, and in the lake trout study, initiated by Wisconsin. Neither of these programs requires description to this audience in which there is such a liberal representation of technicians from the Great Lakes States, but they are mentioned here to round out the picture of State-Federal cooperation.

I hope that no one will infer that this selective and incomplete listing of cooperative projects in fisheries development and conservation represents the sum total or even the preponderant majority of functions of the Service. There are many fields in which the Service must assume full

responsibility and cannot share the burden with State agencies. These include the many functions assigned by law to the Fish and Wildlife Service. I shall not attempt to cite them all but shall be content to characterize them merely as functions concerned with the public domain, with the territories or with the activities of our citizens on the high seas, all of which are defined by the Constitution as delegated powers of the Federal Government. All such spheres of activity lie beyond the field of interest of any one State, or involve problems of such magnitude that no single State can undertake their solution. In the latter category, we find the research functions delegated to the Fish and Wildlife Service by interstate compact and approved by Congressional Act. Among the functions concerned with territories are the outstanding ones of management of the Alaska fisheries and management of the fur-seal industry on the Pribilof Islands. This latter is a Federal function by virtue of international treaty.

Salmon still are the basis for the Territory's most important industry, after almost 85 years of commercial utilization. They are the mainstay of Alaska's economy and her chief source of employment and tax revenue. About 30,000 persons are engaged in this industry which annually yields products worth about \$100,000,000.

Because Alaska is a Territory, and because the salmon industry there is represented by investments primarily of residents of the continental United States, management of this natural resource has been reserved to the Federal Government as being of national concern rather than of local importance.

In administering the salmon fisheries of Alaska, the Service carries on research to develop the facts concerning natural history, abundance, and changes in abundance and the reasons therefor, of the five species of salmon in the various areas of the Territory. Field observations annually indicate the number of salmon ascending the streams to spawn, and in Southeastern Alaska where an intensive study of pink salmon is in progress, downstream migrants are counted in representative streams to provide an index to the success of spawning. An accumulation of these data has provided a sort of actuarial table upon which forecasts of future runs are based. Where the downstream migrations are not measured, such forecasts are based only upon the extent to which the spawning grounds are seeded in the parent cycle.

The forecasts based upon escapement only are less reliable than those based upon escapement plus fresh-water survival rate. But even where both extent of spawning and degree of survival are known, wholly unexpected losses may develop, as in Southeastern Alaska this year. The escapement in the parent year, 1951, for the Southeastern Alaska pink salmon run was good throughout the area comprising almost 1,000 spawning streams. The downstream migration, as evaluated in six representative streams in various parts of the area, indicated a very high survival rate, in fact, one of the highest in the 13 years during which this work has been carried on. There was every reason to believe that the run of pink salmon in this area in 1953 would be at least of normal proportions—able to yield a

pack of 1,800,000 cases and still provide for an adequate spawning reserve. Instead, the run yielded only 350,000 cases, and it remains to be seen whether the restrictions that were imposed were adequate to reserve more than a meager escapement. Pink salmon continue to enter the streams in some parts of Southeastern Alaska until early October, and we do not yet have a complete evaluation of this phase of the run.

A somewhat similar situation developed in the pink salmon-producing areas of northern British Columbia this year also. There had been a good escapement in the preceding cycle and the outlook was for normal runs in 1953. Small runs developed, and fishing was curtailed to reserve an adequate brood stock.

This failure to forecast with reasonable accuracy the run of pink salmon in Southeastern Alaska was very costly to the industry and apparently resulted from our lack of knowledge of the factors affecting the survival of salmon in the ocean. Forecasts, based upon escapement and survival factors in the past, have been reasonably reliable, and it had been assumed that factors affecting the life of salmon in the ocean were fairly constant from one year to the next. A determination of the ocean factors responsible and an annual estimate of their effect on the runs would refine our forecasts of abundance with a financial saving to the industry, and greater safeguard for the salmon themselves in the form of protective regulations when unfavorable conditions prevail. We are going to try to find a way to tackle this problem.

Pink salmon, because of their two-year life cycle, respond quickly to protection, and our regulations must be designed to allow an escapement of a size which, over the years, will provide the maximum return. The results cannot be judged by the experience of one year, as in the case of the disastrous pink salmon run in 1953, but by the results achieved over a period of years.

Duties of the Fish and Wildlife Service on the high seas are concerned with the promotion and development of commercial fisheries and the conduct of necessary researches upon which sound management must rest; for example, the Pacific Oceanic Fishery Investigations, based in Hawaii, and the studies required to satisfy commitments of the two principal high seas fisheries treaties, the International Convention for the Northwest Atlantic Fisheries, and the International Convention for the High Seas Fisheries of the North Pacific Ocean. Even these duties are the concomitant of cooperation in a larger sense; that is, cooperation between the interested maritime nations in the proper development and conservation of high seas fishery resources.

With Federal spending reduced, the maintenance of functions which are essential to the conservation of aquatic resources will require the most careful planning and the application of the most effective business management. Doubtless those functions which are prescribed by law and which can be performed only by the Federal fishery service will of necessity continue with little change in the scale of operations, but serious

budgetary reduction will require the trimming of projects which are the responsibilities of several agencies.

I do not wish to be considered pessimistic, but it is only business prudence to foresee and forestall the effects of a curtailment of Federal services. Surely the best way to cushion the effects of reductions in appropriations is to plan in advance for wider cooperation among interested agencies. I think the States, the fishing industry, the anglers, the general public, and the Fish and Wildlife Service, should look forward to a period of greater individual service and the necessity as well as the advantages of pooling resources and efforts to accomplish the required tasks.

BIBLIOGRAPHIC SOURCES FOR FISHERY STUDENTS AND BIOLOGISTS

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INTRODUCTION

To review the literature concerning a particular field of fishery biology and to keep abreast of recent developments are formidable problems, for the results of research have been published in numerous journals and in various languages for several centuries. Fortunately, there are bibliographic and abstract journals, compendia, and special bibliographies, which are of valuable assistance to the research worker. The purpose of this paper is to present an annotated list of some of these research aids. Other bibliographic references—textbooks, scientific expedition reports, and scientific papers published in various journals or series—have been omitted, since they are widely known and used by all students and research workers.

I have included both fishery literature and zoological literature pertaining to fishery or to related studies. Little has been included about insects, birds, and mammals, all of which are treated by special bibliographic or abstracting services, nor has detailed information on the literature of physiology, chemistry, physics, and allied subjects been included, although those branches of science often have important roles in fishery research.

In preparing this paper, I have obtained valuable data from Roger C. Smith's *A guide to the literature of the zoological sciences*, Burgess Pub. Co., 114 pp., 1945, a comprehensive and valuable account of the sources of general zoological literature. This article can be considered as a special elaboration of Smith's publication. Included herein are more detailed descriptions of certain of Smith's references, together with others of particular interest to fishery workers, which were omitted from Smith's work.

The value and accuracy of the literature aid depend upon the thorough-

ness of the compilers and editors and never is the literature covered completely and without error. In using the following listing of journals, monographs, . . . the research worker should realize that omissions and inaccuracies, although negligible, almost surely occur.

BIBLIOGRAPHIC JOURNALS

Bibliographies represent the results of the collection and compilation of the literature references. Several serial publications exist or have existed as bibliographic journals to compile references to biological papers and so make them available to research workers. As these journals are of considerable value to biologists, I have in the following account given brief notes on each serial and, for some journals, an illustration of the various subjects for which references are shown.

Bibliographic Index. (1937—). This cumulative bibliography of bibliographies appears quarterly. More than 1,500 periodicals are examined regularly, and references are made to those articles which contain bibliographies. Complete or comprehensive bibliographies are starred. The index is by subject only. The annual volume for 1949, which contained material from the June, September, and December issues, plus additional material, has pertinent references under Biology, Fishes, Natural History, Marine Biology, Ocean, and Zoology.

Bibliographica Oceanographica. (1929—). (Vol. 16, 1943, received in 1950). This serial developed from Giovanni Magrini, 1929, *Essai d'une bibliographie général des sciences de la mer, année 1928*. References are compiled from over 100 journals. The text is printed in either Latin or Italian, but the references are given in their original languages. Volume 15, 1942, was found to have the references classified in the following categories: 1. General; 2. Physical Oceanography; 3. Biological Oceanography; and 4. Fishing. Under General are listed: Navigation; Marine Works, and Others. The Physical Oceanography section is subdivided into further categories: General; Marine Geology; Marine Geography; Marine Chemistry and Physics; Dynamics of the Sea; and Geophysics. Subdivisions under Biological Oceanography include: General; Methods, Anatomy and Physiology of Marine Animals; Botanical Anatomy and Physiology; Reproduction; Growth of the Embryo and Body Growth; Biochemistry; Ecology; Plankton and Benthos; Systematic and Descriptive Zoology, Botany, Paleobiology, and Phylogeny. The Fishing section contains the subdivisions: General; Fishery Economy and Legislation; Application of Biology to Fishing; Fishing Ports; Fishing Methods and Gear; Fishing Localities; Fishery Products; Nutritional Value of Fishery Products; Markets; Fishery-Products Industries and Commerce in Various Regions; By-products of the Fisheries; and Preservation. Most of the above subdivisions are broken down into further classifications. In all cases the numbers of references are large.

Bibliographia Zoologica. (1896–1934, suspended 1916–1920). This

serial was dependent upon the Concilium Bibliographicum for references. In the 194 pages of Volume 43, 1934, the following divisions are considered of interest to fishery biologists: Paleontology; General Biology; Microscopy, Preservation; General, Periodical, and Society Publications; Museums, Stations, and Aids to Study; Collected Publications and Histories; Physiology, Embryology, Anatomy, Ecology, Economic Zoology, and Histology; Zoogeography; Invertebrata, and Protozoa—Mammalia—Bimana.

Journal of the Society for the Bibliography of Natural History. (1936-). According to Volume 1, Part 2, this English organization "is a scientific society instituted for the study of the bibliography of all branches of zoology, botany and geology". Volume 1 has 12 parts including 488 pages. Volume 2 has 5 parts to date (September 1949), including 184 pages. This journal has published some historical items on natural history, but few detailed bibliographies.

Zoological Record. (1864-). This journal is most important for all zoologists. Published by the Zoological Society of London, it is so well known and readily available at most scientific libraries that a detailed discussion of it is unnecessary.

ABSTRACT JOURNALS

The above-mentioned bibliographic journals give only references to the scientific literature. Abstract journals, such as the seven listed below, publish summaries or reviews of the more important papers and often also include some bibliographic references.

Berichte über die wissenschaftliche Biologie. (1926-). Band 61, 1943, the most recent available, was examined. Some divisions of possible interest to fishery workers follow: General; Methods; Morphology of Animals; Biochemistry and Physiological Chemistry; Metabolic Physiology of Animals; Stimulatory Physiology of Animals; Developmental Physiology of Animals; Evolution Research; General Biology; Biological Geography; Hydrobiology (including fishery biology); Symbiosis and Parasitism; Plant and Animal Diseases; Systematic Monographs. This serial is published monthly.

Biological Abstracts. (1926-). This is the most important abstract journal for zoologists. Like the Zoological Record, it is so well known and so readily available that a discussion of its contents is unnecessary. It is sponsored by the Union of American Biological Societies and is published monthly.

Commercial Fisheries Abstracts. (1947-). This monthly "summary of important developments for the fishery industries" is published by the Fish and Wildlife Service, U. S. Department of the Interior. The abstracts are printed in the shape of 3- by 5-inch cards, four to a page. The cards can be cut out and filed. In addition to the abstracts, a small bibliographic section lists publications of secondary importance. A typical issue,

Volume 3, No. 4, April 1950, had 40 abstracts and 51 bibliographic references.

World Fisheries Abstracts. (1950-). This bi-monthly review of technical literature on fisheries and related industries is published by the United Nations' Food and Agriculture Organization. The abstracts are similar in form to those of Commercial Fisheries Abstracts and are derived largely from that publication. English, French, and Spanish editions are available. Volume 1, No. 1, contained 63 abstracts in addition to a 2-page "Technological News" section which was devoted to notes on the results of unpublished research.

Zentralblatt für Zoologie, allgemeine und experimentelle Biologie. (1912-1918). This was a continuation of *Zoologisches Zentralblatt* (1894-1912) and *Zentralblatt für allgemeine und experimentelle Biologie* (1910-1912). The references in the last volume (No. 6) were arranged by phyla and classes and also by numerous divisions of which the following are important to fishery students: Bibliography; Ecology; Geographic Distribution; Oceanography; Marine Fauna; Fresh-water Fauna; Fishery Biology; and Nature Conservation.

Zoologischer Bericht. (1922-). This serial classifies, lists, and abstracts zoological publications. Section A11, Ecology, Ethnology, and the sections on Mollusca, Crustacea, and Pisces are of special interest to fishery students. It has a detailed index by subject and genus. Band 55, 1943-1944, has 1,764 abstracts.

Zoologischer Jahresbericht. (1879-1924). This journal, published by the Zoological Station of Naples, included bibliographies and abstracts listed by phyla and (in earlier editions) also by general subject. The reviews or abstracts of the most recent findings in each animal group were presented by authorities in that particular field. The last number, published in 1924, covered the year 1913.

JOURNALS WHICH INCLUDE BIBLIOGRAPHIES OR ABSTRACTS

In addition to those which are devoted entirely to bibliographies or abstracts, there are other journals which, incidental to scientific papers, include references or reviews of current literature. Such journals are extremely valuable, since they often publish these data several years before the bibliographic or abstract journals are able to do so. A list of journals which generally contain notes on current literature follows:

Aarsberetning vedkommende Norges Fiskerier. Since 1937, a list of fishery literature has been published in the annual report of Norwegian fisheries. The first publication, by Einar Kofoed, covered the period 1880-1936 and is found in the report for 1937, Nr. 6. A typical issue, that appearing in the report for the year 1947, classified fishery articles under the three main divisions of Marine Fish and Fisheries, Fresh-water Fisheries, and Whaling and Sealing. These divisions were subdivided into various biological, technological, and economic categories.

American Midland Naturalist. (1909–). A bi-monthly journal; Volume 44, No. 1, July 1950, had 19 reviews of new biological books.

American Naturalist. (1867–). A bi-monthly serial, this journal contains a "Reviews and Comments" section dealing with current publications.

American Scientist. (1913–). This quarterly serial is published by the Society of Sigma Xi. Volume 38, No. 3, July 1950, had 19 reviews of new books in "The Scientist's Book Shelf" section.

Annalen der Hydrographie und Maritimen Meteorologie. Zeitschrift für Seefahrt- und Meereskunde. (1873–1943). Heft 11, for the year 1943, contained 100 bibliographic references listed under: Instrument and Apparatus Information; Astronomy; Terrestrial and Astronomical Navigation; Descriptions of Coasts and Harbors; Vessel Operation and Vessel Construction; and Miscellaneous.

Archiv für Fischerei-Wissenschaft. (1948–). This publication is sponsored by the Institut für Küsten- und Binnenfischerei der Bundesanstalt für Fischerei and the Deutsches Hydrographische Institut, both of Hamburg. Jahrgang 2, Heft 1/2, had reviews of five books on fishery and related subjects.

Archiv für Hydrobiologie. (1893–). From 1893 to 1905, this German serial was known as *Forschungsberichte aus der biologischen Station zu Plön*. Band 42, N. F., Heft 4, 1949, was examined. Eight books were reviewed and 353 references were given to recent hydrobiological literature.

Biological Reviews. (1923–). This quarterly journal, published by the Cambridge Press at London, contains reviews and summaries of recent biological researches.

Biologisches Zentralblatt. (1881–). This monthly journal has reviews and summaries of books and papers. The 10 numbers of Band 68, 1949, had 21 reviews.

Biologist. (1916–). This quarterly journal is published by Phi Sigma Society. Volume 31, No. 3, February 1949, had 77 reviews of new books.

Commercial Fisheries Review. (1938–). In addition to articles about the commercial fishing industry, this monthly publication of the Fish and Wildlife Service, U. S. Department of the Interior, has a section which lists and abstracts recent fishery articles. The May 1950 issue included 32 abstracts of fishery publications.

Copeia. (1913–). Published by the American Society of Ichthyologists and Herpetologists, this quarterly journal has a section devoted to reviews and comments on recent literature. The June 30, 1950, issue contained reviews of nine books on fish and reptiles.

Ecology. (1920–). This quarterly journal, devoted to all phases of ecological biology, is published by the Ecological Society of America.

Both book reviews and book notices are presented, the latter being more abbreviated. Volume 31, No. 1, January 1950, had 6 book reviews and 19 book notices.

Die Fischwirtschaft. (1949-). This German monthly periodical, published as *Fischereiwelt* until September 1952, is of interest primarily to those concerned with the marine fisheries. Heft 2, February 1950, of the second volume, had reviews of three new fishery books.

Food and Agriculture Organization of the United Nations, Fisheries Bulletin. (1948-). In Volume 3, No. 1 (January-February 1950), under "Notes on Publications," there were 18 abstracts of fishery articles.

Hydrobiologica. Acta Hydrobiologica, Limnologica et Protistologica. (1948-). This quarterly journal is devoted to investigations in the general field of zoo- and phytobiology of marine and fresh-water forms. Volume 2, No. 3, 1950, had an annotated bibliography of 23 articles.

Internationale Revue der gesamten Hydrobiologie und Hydrographie. (1908-1943). The volume for 1938 has reviews of 72 articles and books. Some of the earlier volumes contain bibliographies and summaries on special problems and references to current literature. Originally devoted to studies of the physics and biology of all waters, this periodical lately contained papers mostly on limnology.

Journal du Conseil Permanent International pour l'Exploration de la Mer. (1926-). This serial includes both reviews and a current bibliography of the science of the seas. It is, perhaps, the fishery biologist's most valuable source of references to recent literature. Volume 16, No. 1, contained reviews of 12 publications and 789 bibliographic references.

Journal of Animal Ecology. (1932-). In this serial, the British Ecological Society includes abstracts of all publications on the animal ecology of the British Isles which are brought to its attention. Volume 19, No. 1, May 1950, had four reviews and a classified, abstract list of 120 titles.

Journal of Ecology. (1913-). This serial has papers and bibliographies on plant ecology, including phases of limnology and oceanography. Volume 38, No. 1, July 1950, had 6 reviews and 93 references to papers of ecological interest reviewed by the British Ecological Society.

Nature. (1869-). This English scientific journal has a monthly supplement listing recent scientific and technical books. In Volume 166, No. 4213, July 29, 1950, there were listed 14 books on general biology, natural history, botany, and zoology.

Progressive Fish-Culturist (1938-). In addition to articles on fish culture and fresh-water fish management, this journal of the Fish and Wildlife Service, U. S. Department of the Interior, often has abstracts and reviews on recent fishery publications. The January 1950 issue included

four abstracts and the "Clearing House" section carried two bibliographic references to recent articles.

Quarterly Review of Biology. (1926-). This periodical contains a section which reviews new biological books. In Volume 24, No. 2, June 1949, there are reviews and brief notices of 80 publications in the whole field of biology.

Science. (1883-). Published weekly by the American Association for the Advancement of Science, this journal has "Book Reviews" and "Scientific Book Register" sections. It also lists publications recently received in its offices. This serial covers the entire field of science; there are many references of interest to fishery workers.

Transactions, American Geophysical Union. (1931-). This bi-monthly journal of the American Geophysical Union has a review, abstract, and bibliography section concerned with recent articles on various geophysical subjects. Volume 31, No. 2, Part 1, for April 1950, had 111 bibliographic references to meteorology, 50 to oceanography, and 48 to hydrology.

Zeitschrift für Fischerei und deren Hilfswissenschaften. (1893-). This German fishery serial contains abstracts of fishery articles, primarily on fresh-water studies. Band 36, Heft 5, has reviews of 9 publications.

COMPENDIA—HYDROBIOLOGY AND FISHERIES

As the zoological fields become more intensively studied and the literature more massive, a definite need arises for manuals which summarize the existing information. Such compendia, many of which are in German, are also valuable because of their detailed bibliographies. There are four of prime importance to the fishery student. For the benefit of those who may be unable to read the language but wish to consult the bibliographies, I have included English translations of the titles of individual publications in the three German compendia.

Die Binnengewässer. Seventeen volumes have been printed in this series on inland waters, although not all are complete. These generally contain extensive bibliographies. The volumes are often catalogued in libraries under the editors E. Naumann and A. Thienemann, rather than by individual authors. Following is a list of the publications for which I have information:

Band 1. Die Binnengewässer Mitteleuropas (Inland waters of central Europe). 255 S., 1926.

Band 2. Bodenablagerungen und Entwicklungstypen der Seen (Bottom deposits and evolutionary types of lakes). 124 S., 1927.

Band 3. Die Tierwelt der unterirdischen Gewässer (Animals of subterranean waters). 176 S., 1927.

Band 4. Der Sauerstoff im eutrophen und oligotrophen Seen (Oxygen in eutrophic and oligotrophic lakes). 175 S., 1928.

Band 5. Das Leben der Wolga (Biology of the Volga). 162 S., 1928.

Band 6. Grundlinien der experimentellen Planktonforschung (Basic principles of experimental plankton investigations). ix + 100 S., 1929.

- Band 7. Die Biologie der Moore (The biology of bogs). 146 S., 1929.
- Band 8. Der Hochgebirgssee der Alpen (The high mountain lake in the Alps). 168 S., 1929.
- Band 9. Einführung in die Bodenkunde der Seen (Introduction to the study of lake bottoms). ix + 126 S., 1930.
- Band 10. Fischereibiologie der Alpenseen (Fishery biology of Alpine lakes). viii + 259 S., 1930.
- Band 11. Grundzüge der regionalen Limnologie (Fundamentals of regional limnology). xiv + 176 S., 1932.
- Band 12. Hydrochemische Methoden in der Limnologie (Hydrochemical methods in limnology). x + 173 S., 1932.
- Band 13. Kohlensäure und Kalk (Carbonic acid and lime). vii + 183 S., 1933.
- Band 14. Der Sauerstoffhaushalt der Seen (Oxygen economy of lakes). viii + 217 S., 1934.
- Band 15. Das Zooplankton der Binnengewässer (Zooplankton of inland waters). xii + 272 S., 1935.
- Band 16. Das Phytoplankton des Süßwassers (Phytoplankton of fresh water).
Heft 1. iii + 342 S., 1938.
Heft 2. Erste Hälfte, v + 366 S., 1941.
Zweite Hälfte, x + 183 S., 1942.
Heft 3. In press.
Heft 4. In preparation.
- Band 17. Die wirtschaftliche und kulturelle Bedeutung der Binnengewässer (Economic and cultural significance of inland waters) xiv + 286 S., 1949.

Fishes of the Western North Atlantic. This is a Memoir series of the Sears Foundation for Marine Research, Yale University. Number 1, Part 1, Lancelets, Cyclostomes, Sharks, has been published and others are in preparation. The first published work contains excellent bibliographies of the subjects treated.

Handbuch der Binnenfischerei Mitteleuropas. This work on the inland fisheries of central Europe has extensive bibliographies. In some libraries these volumes are indexed under the editors, R. Demoll and H. N. Maier. Six volumes have been published; information on them follows:

- Band 1. Das Wasser und seine Bewohner (Water and its inhabitants).
Die Gewässer Mitteleuropas. Ein hydrobiologische Charakteristic ihre Haupttypen (Waters of central Europe. A hydrobiological description of their principal types). S. 1-84, 1924.
Die Mikroflora des Süßwassers und ihre Bedeutung für den Haushalt der Gewässer (Microflora of fresh water and its role in the aquatic community). S. 85-144, 1924.
Die Nahrungstiere der Fische (Animal food of fish). S. 145-228, 1924.
Die Fischfeinde aus der höheren und niederen Tierwelt (Enemies of fish from the higher and lower animal kingdom). S. 229-474, 1924.
Verzeichnis (Index). S. 475-479, 1924.
- Band 2B. Physiologie der Süßwasserfische Mitteleuropas (Physiology of the fresh-water fishes of central Europe). 340 S., 1936.
- Band 3. Systematik und Biologie (Systematics and biology).
Lieferung 1. Die Süßwasserfische Deutschlands. Eine tiergeographische Skizze (Fresh-water fishes of Germany. A zoogeographic sketch). S. 1-32, 1926.
Lieferung 2. Einführung in die Systematik der Süßwasserfische Mitteleuropas (Introduction to the systematics of the fresh-water fishes of central Europe). S. 33-51, 1928.
Lieferung 3. Die Stachelflossen (Acanthopterygii). S. 52-100, 1928.
Die Weichflossen (Anacanthani). S. 101-110, 1929.

- Die Plattfische (Heterosomata). S. 111–129, 1929.
 Die Stichlinge (Gasterosteidae). S. 130–141, 1929.
 Die Welse (*Silurus glanis* and *Ameiurus nebulosus*). S. 142–158, 1929.
 Lieferung 4. Der Flusaal (*Anguilla vulgaris*). S. 159–217, 1930.
 Lieferung 5. Die Lachsartigen (Salmonidae) I. S. 218–370, 1937.
 Lieferung 6. Die Lachsartigen (Salmonidae) II. Coregonidae. S. 371–501, 1941.
 Lieferung 7. *Osmerus artedii*. S. 502–551, 1941.
 Band 4B. Fischereiwirtschaft. I. Geschichte der Binnenfischerei.
 II. Teichwirtschaft und künstliche Fischzucht (Fishing industry. I. History of fresh-water fisheries. II. Pond management and artificial propagation of fish).
 Lieferung 1. Die Geschichte der Binnenfischerei von Mitteleuropa (History of the central European inland fishery). S. 1–52, 1925.
 Teichdüngung (Pond fertilization). S. 53–158, 1925.
 Lieferung 2. Salmonidenzucht in Mitteleuropa (Salmon culture in central Europe). S. 159–348, 1931.
 Lieferung 3. Karpenzucht (Carp culture). S. 349–406, 1934.
 Lieferung 4. Teichwirtschaft und Geflügelzucht in ihren Wechselbeziehungen (Pond management and poultry breeding, their interrelations). S. 407–482, 1934.
 Lieferung 5. Grundlagen der allgemeinen fischereilichen Produktionslehre (General principles in the field of fish production). S. 483–662, 1934.
 Lieferung 6. Die Schleienzucht (Tench culture). S. 663–721, 1939.
 Die Zucht des Zanders in Karpenteichwirtschaften und in freien Kewässern (Culture of *Lucioperca* in carp ponds and in open waters). S. 722–748, 1939.
 Lieferung 7. Die Hechtzucht (Pike culture). S. 749–787, 1940.
 Die medizinische Blutegel und seine Bedeutung in der Wasserwirtschaft (The medicinal leech and its significance in the management of waters). S. 788–811, 1940.
 Lieferung 8. Fischerei Futtermittelkunde (Study of fish foods). S. 812–922, 1945.
 Band 5. Die Fischerei in den Flüssen, Seen und Strandgewässern Mitteleuropas (The fishery in the rivers, lakes and inshore waters of central Europe). S. 1–422, 1926.
 Der Flusskrebs, seine Verwandten und die Krebsgewässer (The crayfish, its relatives, and crayfish waters). S. 423–524, 1926.
 Perlen und Perlenmuscheln (Pearls and pearl mussels). S. 525–552, 1926.
 Ergänzungs-Band zu Band 5.
 Lieferung 1. Netzkonservierung im Fischereibetrieb (Net preservation in the fishing industry). S. 1–99, 1941.
 Lieferung 2. Die Wollhandkrabbe (The mitten crab). S. 100–140, 1942.
 Band 6. Fischereischutz; Fischverwertung. Fischereirecht und Organisation (Fishery protection; fishery economics. Fishery regulations and organization).
 Lieferung 1. Anlage und Betrieb von Fischpässen (Installation and operation of fishways). S. 1–137, 1924.
 Lieferung 2. Die Reinhaltung unserer Fischgewässer (How to keep our fish waters clean). S. 138–221, 1926.
 Die Reinigung von Abwässern in Fischteichen (Purification of sewage in fish ponds). S. 222–262, 1926.
 Lieferung 3. Abwässerbeseitigung und Gewässerunreinigung (Sewage disposal and water pollution). S. 263–287, 1928.
 Toxikologie der Fische (Toxicology of fish). S. 289–342, 1928.
 Lieferung 4. Die Erhaltung und Pflege der Fischgewässer (Maintenance and care of water for fish). S. 343–416, 1937.

Handbuch der Seefischerei Nord-Europas. This publication deals with the sea fisheries of northern Europe. Ten volumes have been printed. In most libraries the volumes are catalogued under the editors, H. Lübbert and E. Ehrenbaum. Information on the volumes follows:

- Band 1. Naturbedingungen des Lebens in Meere (Natural conditions of life in the sea).
- Heft 1. Die waagerechte Gliederung und die Tiefen des Meeres (Stratification and the depths of the ocean). iii + 23 S., 1949.
 - Heft 2. Die natürlichen Eigenschaften der Gewässer (Natural properties of water). iii + 37 S., 1949.
 - Heft 3. Die Bodenbedeckung der nordeuropäischen Meere (Bottom deposits of the North European seas). iii + 33 S., 1949.
 - Heft 4. Die festsitzenden Pflanzen der nordeuropäischen Meere (Sessile plants of the North European seas). iii + 54 S., 1930.
 - Heft 5a. Die Nahrung der Meerestiere (Nutrition of marine animals). I and II. iii + 85 S., 1950.
 - Heft 5b. Die Nahrung der Meerestiere (Nutrition of marine animals). III and IV. (In press).
 - Heft 6. Der Stoffhaushalt im Meere (Metabolism of the sea). iv + 37 S., 1933.
- Band 2. Die Seefische Nord-Europas. Naturgeschichte und wirtschaftliche Bedeutung der Seefische (Marine fishes of northern Europe. Natural history and economic importance of the marine fishes). x + 377 S., 1936.
- Band 3. Systematik und Biologie anderer wirtschaftlich wichtiger Meerestiere Nord-Europas (Systematics and biology of other economically important North European marine animals).
- Heft 1. Wale, Robben (Whales, seals). v + 54 S., 1937.
 - Heft 2. Krebse und Weichtiere (Crustacea and Mollusca). vi + 147 S., 1929.
 - Heft 3. Seemoos (Bryozoa). vi + 34 S., 1938.
- Band 4. Die wichtigsten Fanggeräte (Principal fishing gears).
- Heft 1/2. Schleppnetze. Waden (Drag nets. Haul seines). xi + 52 S., 1942.
 - Heft 3. Stehende Geräte und Treibnetze (Stationary gear and drift nets). xi + 48 S., 1940.
 - Heft 4. Angeln (Angling). iv + 48 S., 1935.
- Band 5. Die Deutsche Seefischerei (German sea fishery)
- Heft 1. Die Nordseefischerei (North Sea fishery). vii + 229 S., 1928.
 - Heft 2. Die Nordsee-Fischereihäfen (North Sea fishing ports). (In press).
 - Heft 3. Die Ostseefischerei (Baltic fishery). vii + 182 S., 1929.
 - Heft 4. Der Walfang (Whaling). iii + 33 S., 1928.
 - Heft 5. Der Walfang seit 1936 (Whaling since 1936). (In press).
- Band 6. Die Seefischerei von Grossbritannien und Irland (Marine fishery of Great Britain and Ireland). xi + 334 S., 1929.
- Heft 1. Geschichtliche Entwicklung der britischen Fischerei (Historical development of the British fishery).
 - Heft 2. Verwaltung und Regelung der Fischerei (Management and regulation of the fishery).
 - Heft 3. Betriebsarten und Fahrzeuge (Fishing methods and ships).
 - Heft 4. Fischereidistrikte und Fischereihäfen (Fishing districts and ports).
- Band 7. Die Seefischereien von Frankreich, Niederlande, Belgien, Island (Marine fisheries of France, Holland, Belgium, and Iceland).
- Heft 1. Die französische Seefischerei (French sea fishery). vii + 180 S., 1937.
 - Heft 2. Die niederländische Seefischerei (Dutch sea fishery). v + 104 S., 1933.
 - Heft 3. Die belgische Seefischerei (Belgian ocean fishery). iv + 39 S., 1932.
 - Heft 4. Die isländische Seefischerei (Icelandic ocean fishery). iv + 89 S., 1930.
 - Heft 5. Austern- und Muschelkultur (Oyster and mussel culture). iv + 64 S., 1932.
- Band 8. Die Seefischereien von Norwegen, Dänemark, Schweden, Finnland, Russland, Estland, Lettland und Danzig (Marine fisheries of Norway, Denmark, Sweden, Finland, Russia, Estonia, Latvia, and Danzig).
- Heft 1a. Die norwegische Seefischerei (Norwegian ocean fishery). x + 181 S., 1938.
 - Heft 1b. Der norwegische Walfang. Der norwegische Robbenfang (Norwegian whaling. Norwegian sealing). xii + 94 S., 1938.

- Heft 2. Die dänische Seefischerei (Danish ocean fishery). v + 108 S., 1931.
 Heft 3a. Die schwedische Nordseefischerei (Swedish North Sea fishery). (In press).
 Heft 3b. Die schwedische Ostseefischerei (Swedish Baltic fishery). iii + 32 S., 1934.
 Heft 4. Die Seefischerei von Finnland (Finnish sea fishery). iv + 73 S., 1934.
 Heft 6. Die Seefischerei von Estland und Lettland (Marine fishery of Estonia and Latvia). iii + 34 S., 1928.
 Heft 7. Die Seefischerei von Danzig (Marine fishery of Danzig). iii + 34 S., 1931.
 Band 9. Verwertung der Seefischereiprodukte (Utilization of marine fishery products).
 Heft 3a. Bratfischhandel, a) in Grossbritannien (Smoked fish trade, a) in Great Britain). iii + 34 S., 1931.
 Band 10. Förderung der Seefischerei (Promotion of the sea fishery).
 Heft 4. Internationale Seefischereistatistik (International marine fishery statistics). iv + 41 S., 1928.

COMPENDIA—GENERAL ZOOLOGY

Three other German compendia are also important sources of bibliographic material. All are concerned with the animal kingdom and contain sections of particular interest to the fishery biologist. The three are as follows:

Bronn's Klassen und Ordnungen des Tier-reichs wissenschaftlichen dargestellt in Wort und Bild. This valuable work, published by C. F. Winter, first appeared in 1859 and has not yet been completed. It deals with the classes and orders of the animal kingdom, is well illustrated, and has voluminous references.

Das Tierreich. Eine Zusammenstellung und Kennzeichnung der rezenten Tierformen. This series is edited by F. E. Schulze, W. Küken-thal, et alia, and is published by Walter de Gruyter and Co. Many of the parts have abbreviated bibliographies for each genus and species.

Kükenthal's Handbuch der Zoologie. Eine Naturgeschichte der Stämme des Tierreichs. This work on the natural history of animal groups contains valuable bibliographies.

SPECIAL BIBLIOGRAPHIES

Usually one must gather the references from masses of scientific literature and compile his own bibliography; however, the research worker may be fortunate enough to find published a fairly comprehensive bibliography of his particular field of interest. A list of such specialized bibliographies, which deal with special fishery or related subjects and consequently are of interest to many fishery workers, follows:

ALBEE, LOUISE RANKIN

1896. The Bartlett collection. A list of books on angling, fishes, and fish culture. Harvard Univ. Library Bibliographical Contrib. No. 51, 180 pp.

ALLEN, E. J.

1926a. A selected bibliography of marine bionomics and fishery investigations. Part I. Physical and biological conditions in the sea. Jour. Cons. Perm. Int. Expl. Mer. Vol. 1, pp. 77-96.

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- AMERICAN GEOPHYSICAL UNION
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1952. Annotated bibliography on hydrology, 1941-1950 (United States and Canada). Washington, U.S. Gov't. Print. Off., v + 408 pp.
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1949. Bibliography on zoology. A source list up to 1948. Battelle Memorial Inst., Columbus, Ohio, 135 pp., mimeographed.
- BAUGHMAN, J. L.
1947. An annotated bibliography of oysters with pertinent material on mussels and other shellfish and an appendix on pollution. Texas A. and M. Res. Foundation, Agr. and Mech. Coll. of Texas, 794 pp.
1949. An annotated bibliography for the student of Texas fishes and fisheries, with material on the Gulf of Mexico and the Caribbean Sea. Texas Game, Fish and Oyster Comm., 240 pp., mimeographed.
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1931. A selected bibliography of chemical literature pertaining to the fish industry. Cal. Fish and Game, Vol. 7, pp. 256-260.
- BINNEY, WILLIAM GREENE
1863. Bibliography of North American conchology previous to the year 1860, prepared for the Smithsonian Institution; Part 1, American authors. Smiths. Inst., Misc. Coll., Vol. 5, 650 pp.
1864. Bibliography of North American conchology previous to the year 1860, prepared for the Smithsonian Institution; Part 2, Foreign authors. Smiths. Inst., Misc. Coll., Vol. 9, 306 pp.
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1880. Chronologisk fortegnelse over skrifter og afhandlinger om de norske fiskerier. Christiania, R. Hviids Enkes, pp. 1-26.
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- BUCHER, DORRIS, MARTIN HEERDT, JR., and KATHRYN OSTERHARG
1949. Bibliography of the preservation of fishery products by freezing. Fish and Wildlife Serv., U. S. Dept. Interior, Fish, Leaflet No. 265, 151 pp.
- CARBINE, WILLIAM F.
1952. Doctoral dissertations on the management and ecology of fisheries. Additional listings—1952. Fish and Wildlife Serv., U.S. Dept. Interior, Spec. Sci. Rept.: Fish. No. 87, 44 pp.
- CARRIGAN, EDWARD J.
1947. Bibliography on the chemical nature of fish. Office of Tech. Serv., U. S. Dept. Commerce. (640 cards on microfilm).
- CARRIKER, M. R., M. F. BUELL, and E. T. MOUL
1950. A preliminary list of the literature on the ecology of the estuaries, with emphasis on the middle Atlantic coast of the United States. Zool. Dept., Rutgers Univ., New Brunswick, N. J., 52 pp., mimeographed.
- CONSEL INTERNATIONAL DES RECHERCHES UNION GÉODÉSQUE ET GÉOPHYSIQUE INTERNATIONALE
1929. Bibliographie des marées (1910-1927). Bull. No. 12, 27 pp.
1931. Tidal bibliography. Bull. No. 17, 14 pp.

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CORWIN, GENEVIEVE

1930. A bibliography of the tunas. Cal. Div. Fish and Game, Fish Bull. No. 22, 103 pp.

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1910. Bibliotheca zoologica Danica 1876-1906. Fortegnelse over Danmarks zoologiske litteratur 1876-1906. Copenhagen, J. L. Lybeckers, xxii + 262 pp.

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- 1916a. Bibliography of fishes. Vol. I, Authors A-K. New York, Am. Mus. Nat. Hist., x + 718 pp.

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SPEIRS, J. MURRAY

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SPEIRS, J. MURRAY, J. M. JOHNSTON, and RUTH KINGSMILL

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1941. Sea of Cortez. A leisurely journal of travel and research with a scientific appendix comprising materials for a source book of the marine animals of the Panamic faunal province. New York, Viking Press, + 598 pp.

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1932. The California barracuda *Sphyraena argentea*. II. A bibliography of barracudas. Cal. Div. Fish and Game, Fish Bull. No. 37, 122 pp.

WEIL, B. H., POAGIE E. MURRAY, GEORGE W. REED, and ROBERT S. INGOLS

1948. Bibliography on water and sewage analysis. Georgia Inst. Tech., State Eng. Exp. Sta., Spec. Rept. No. 28, 215 pp.

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1883. Bibliotheca piscatoria. London, W. Satchell, xxiv + 397 pp.

WHEELER, GENEVIEVE C.

1931. A bibliography of the sardines. Cal. Div. Fish and Game, Fish Bull. No. 36, 133 pp.

WOOD, CASEY A.

1931. An introduction to the literature of vertebrate zoology based chiefly on the titles in the Blacker Library of Zoology . . . and other libraries of McGill University. London, Oxford University Press, xix + 643 pp.

GENERAL BIBLIOGRAPHIES

There are a few bibliographies whose combined information covers the zoological field from the eighteenth to the latter part of the nineteenth century. Because of the great increase in scientific research and publishing after 1880, similar general bibliographies on zoology would be of tremendous size. As a substitute for these long-term bibliographies, smaller ones have been developed which cover periods of only a year and are published annually. These were mentioned previously as bibliographic journals. Information on the general bibliographies follows:

Bibliotheca Historico-Naturalis. Verzeichniss der Bücher über Naturgeschichte welche in Deutschland, Scandinavien, Holland, Frankreich, Italien und Spanien in den Jahren 1700-1846 erschienen

sind. Compiled and published by Wilhelm Engelmann in Leipzig, this work of viii + 786 pages has three main divisions: Aides, History of Natural Sciences, and Zoology. In the Aides section are included the subdivisions: Bibliographies, Museums, and Nature Societies; Taxidermy; and Microscopy. Under the History of Natural Sciences section are also subdivisions concerning: Publications of Learned Societies and Miscellaneous Natural History Publications. The Zoology division has references to the following subdivisions: Comparative Anatomy and Physiology; Miscellaneous Zoological Publications; Books on Particular Animal Classes; and Prehistoric Animals (and Plants).

Bibliotheca Zoologica. Verzeichniss der Schriften über Zoologie welche in den periodischen Werken enthalten und vom Jahre 1846-1860 selbständig erschienen sind. This work was compiled by J. Victor Carus and Wilhelm Engelmann and published by the latter in Leipzig. Volume 1 has 950 pages, and Volume 2 has xxiv + pp. 951-2,144. These two volumes are somewhat similar to *Bibliotheca Historico-Naturalis* in their divisions and subdivisions. Volume 1 contains references on the natural sciences in general and on invertebrates, whereas Volume 2 is concerned with vertebrates and paleontology.

Bibliotheca Zoologica II. Verzeichniss der Schriften über Zoologie welche in den periodischen Werken enthalten und vom Jahre 1861-1880 selbständig erschienen sind. The eight volumes were edited by O. Taschenberg and published by Engelmann at Leipzig. The general plan of this work is patterned after the two preceding works, *Bibliotheca Historico-Naturalis* and *Bibliotheca Zoologica*.

Volume 1, 1887, pp. xvii + 1-864, contains references to natural sciences in general, including literature, aides, history, and travel, and general references to zoology. Volume 2, 1889, pp. viii + 865-1,730, has references to the literature concerning the lower invertebrates. Volume 3, 1890, pp. iv + 1,731-2,760, covers the remainder of the insect literature. Volume 4, 1894, pp. v + 2,761-3,648, deals with bryozoans, brachiopods, mollusks, and the lower chordates. Volume 5, 1899, pp. vi + 3,649-4,708, is concerned with birds and mammals, and Volume 6, 1905, pp. vii + 4,709-5,512, has references to paleozoology. Volume 7, 1910-1921, pp. viii + 5,513-6,256, is a supplement with corrections, completions, and additions to the other six volumes.

Catalogue of Scientific Papers. Compiled by the Royal Society of London, this catalogue contains lists by authors of all scientific papers appearing in 1,555 journals between 1800 and 1900. It is extremely useful for referring to the works of known authors.

Volumes 1-6, 1867-1872, cv + 5,743 pp., lists the scientific papers published between 1800 and 1863; Volumes 7-8, 1877-1879, xxxi + 2,357 pp., list the papers between 1864 and 1873; Volumes 9-11, 1891-1896, xxxii + 2,966 pp., concern the period 1874-1883; Volume 12, 1902, xxxii

+ 807 pp., is a supplementary volume for the period 1800-1883; and Volumes 13-19, 1914-1925, cx + 7,038 pp., cover the years 1884 to 1900.

INDEXES TO REPORTS ON FISHERIES AND ALLIED SUBJECTS

Some of the organizations dealing with fishery and allied matters have issued indexes to their past publications. These indexes are valuable sources of bibliographic references to fisheries studies. Some of them are listed below:

AMERICAN FISHERIES SOCIETY

1929. Index to transactions of American Fisheries Society, volume I-LVIII, (1872-1928), 99 pp. [Another index for years after 1928 is in preparation.]

CALIFORNIA DIVISION OF FISH AND GAME

1947. Publications of the California Fish and Game Commission. Cal. Fish and Game, Vol. 33, pp. 35-51. [this supersedes Bryant, Harold C., 1921. Publications of the California Fish and Game Commission, 1870-1920. Cal. Fish and Game, Vol. 7, pp. 87-98.]

CARNEGIE INSTITUTE OF WASHINGTON

1948. Catalogue of publications and depositories of the institution. Washington, Carnegie Institution of Washington, vii + 388 pp.

CONSEIL PERMANENT INTERNATIONAL POUR L'EXPLORATION DE LA MER

1939. Index to publications by the International Council for the Exploration of the Sea, 1899-1938. 145 pp.

DANISH BIOLOGICAL STATION

1952. Index to the reports of the Danish Biological Station, Nos. I-LIV (1891-1952). Rep. Dan. Biol. Sta., No. 54, pp. 47-54.

FISHERIES RESEARCH BOARD OF CANADA

1950. List of publications of the Fisheries Research Board of Canada, 1901-1949. Fish. Res. Bd. Can., Bull. No. 87, 96 pp.

FULTON, T. WEMYSS

1905. General index to the scientific reports of the Fishery Board for Scotland, 1883-1904, with a list of the papers contained in them. 23rd Ann. Rept. Fish. Bd. Scot., 1904 (1905), Pt. III, Sci. Inv., Rept. No. IX, pp. 166-250.

INTERNATIONAL HYDROGRAPHIC BUREAU

1935. Index of articles and authors for the first twenty-four numbers, March 1923- November 1935. Hydrographic Rev., 70 pp.

1942. Index of articles and authors for numbers 25 to 36 inclusive issued from May 1936 to November 1941 inclusive (Vol. 13 to Vol. 18 inclusive). Hydrographic Rev., 37 pp.

MACDONALD, ROSE M. E.

1921. An analytical subject bibliography of the publications of the Bureau of Fisheries 1871-1920. Rept. U. S. Comm. Fish. 1920 (1921), App. No. 5, 306 pp.

MARINE BIOLOGICAL ASSOCIATION OF THE UNITED KINGDOM

1913. List of publications recording the results of researches carried out under the auspices of the Marine Biological Association of the United Kingdom in their laboratory at Plymouth or on the North Sea Coast from 1886-1913. Jour. Mar. Biol. Ass., Vol. 10 (N.S.), pp. 143-178.

MICHIGAN DEPARTMENT OF CONSERVATION

1950. Publications of the Institute for Fisheries Research, 1930-1949. 20 pp.

OFFICE SCIENTIFIQUE ET TECHNIQUE DES PECHES MARITIMES

1948. Bibliographie analytique des publications de l'Office Scientifique et Technique des Pêches Maritimes. Notes et Rapports (N.S.), No. 3, 72 pp.

RITCHIE, ALFRED

1940. General index to the reports and papers issued by the Fishery Board for Scotland on the subject of scientific investigation from 1905-1937, inclusive. Fish. Bd. Scot., Sci. Inv., 1939, No. 2, 63 pp.

SMITHSONIAN INSTITUTION, UNITED STATES NATIONAL MUSEUM

1947. A list and index of the publications of the United States Museum (1875-1946). U. S. Nat. Mus. Bull. No. 193, 306 pp.

WASHINGTON ACADEMY OF SCIENCES

1953. Index to the journal and proceedings of the Washington Academy of Sciences. vi + 268 pp.

YEAGER, LEE E.

1950. Ten year index to the Journal of Wildlife Management. Wildlife Soc., 53 pp.

ACKNOWLEDGMENTS

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OBSERVATIONS ON THE LONGNOSE SUCKER IN YELLOWSTONE LAKE¹

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ABSTRACT

An investigation was made of the food, spawning runs, age and growth, and distribution of the longnose sucker *Catostomus catostomus* in Yellowstone Lake during the summers of 1951 and 1952. This fish was probably accidentally introduced into Yellowstone Lake by bait fishermen in the early thirties. As many as 2,000 specimens were observed with the annual cutthroat-trout runs in Pelican Creek during the early forties. A total of 1,150 was counted there in 1951. The food of suckers captured in the mouths of tributary streams showed an incidence of 69 percent algae, 40 percent higher aquatic plants, and numerous aquatic insects, particularly Diptera. During the spawning run the largest number of suckers entered the traps on the days when water temperatures were highest. Females were significantly larger than males. The average time spawning fish stayed in Pelican Creek was 19 days for females and 17 days for males. The average loss of weight for spawning females was 4.7 ounces and for males 1.8 ounces. A sample of sucker fry captured on July 9 averaged 13 millimeters in total length. Young taken October 11 averaged 30.5 millimeters. The calculated total lengths for each year of life based on 525 specimens were as follows: first year—2.0 inches; second—4.8; third—8.5; fourth—11.7; fifth—13.6; sixth—15.8; seventh—17.4; eighth—18.1. Females grew more rapidly than the males and reached a larger size. Tagging experiments showed that suckers have a rather restricted range and are frequently taken by pelicans.

INTRODUCTION

The best available reports indicate that the longnose sucker was not native to Yellowstone Lake in Yellowstone National Park, Wyoming. It is presumed that this species was accidentally introduced into this lake by live-bait fishermen from adjacent habitat streams such as the Shoshone or Yellowstone (below the falls).

According to Mr. William Dunn, superintendent of the fisheries station on the lake, the first suckers observed were captured by seine on the shoal

¹ Contribution from Montana State College, Agricultural Experiment Station Project No. MS 844, Paper No. 314, Journal Series and the Montana Fish and Game Department.

near the museum at Fishing Bridge during the early thirties (1931-1933). By the mid-thirties a few appeared along with the spawning runs of cut-throat trout in Pelican Creek, which enters the lake about one and one-half miles to the east of the lake outlet, and by the late thirties these runs increased to 300-400 specimens (Simon, 1939, reports 382 for 1938). In the early forties there was estimated to be 1,500-2,000 suckers in each year's run. During this period the fish-traps were kept in operation after the regular trout run was over for the express purpose of capturing the later run of suckers. All suckers captured were destroyed.

Rough counts of specimens made by the hatchery crews at the Pelican Creek traps for the years 1947, 1949, and 1950 were 1,863, 1,057 and 1,302, respectively. The number counted by the junior author in 1951 was 1,150.

Although no early distribution records were kept, it appears that the place of introduction of the sucker was in the vicinity of the lake outlet near Fishing Bridge. All specimens known to have been taken came from this area even though fish-cultural operations were being carried out on tributaries in other parts of the lake.

In 1948 Mr. Dunn reported a few suckers in Clear Creek, which enters the lake approximately 10 miles east of the lake outlet. About 20 were taken in 1950-1951 in Chipmunk Creek which is tributary to the South Arm, approximately 20 air miles from the lake outlet. Four adult specimens were captured in 1951 in Arnica Creek, tributary to the Thumb region, and about 60 young specimens were collected from another small creek in this vicinity by "shocking" in 1952.

The sucker is pretty well distributed around the lake at the present time, although the main concentration is found in the vicinity of the lake outlet and the mouth of Pelican Creek.

An investigation of the longnose sucker in Yellowstone Lake was made during the summer of 1951 and in the early summer of 1952 to secure information on the food habits, life history, and distribution of this species in the lake. Some scale samples used in the age and growth study were collected by Dr. Oliver B. Cope in the summer of 1950. This project was in cooperation with the U. S. Fish and Wildlife Service and the Yellowstone National Park Service. Dr. Oliver B. Cope assisted in directing the study and much valuable information was furnished by Mr. William Dunn. Specimens were positively identified by Dr. Robert R. Miller.

FOOD HABITS

The food habits of the sucker were ascertained by stomach examinations of 74 specimens collected in the mouths of two tributary streams: Pelican Creek and a small unnamed creek which enters the West Thumb. Efforts to secure specimens from the lake proper were futile, largely because the use of gill nets was prohibited. Only five lake specimens containing food were available for study. It would not be safe to conclude that the food of suckers living in the lake is the same as that of individuals in the tributaries.

The writers are not acquainted with any extensive food studies for this species. Simon (1939) reports that longnose suckers are specialized feeders in that their diet consists principally of plant materials (algae). Neave and Bajkov (1929) examined the stomachs of about 100 *Catostomus catostomus lacustris* from Annette Lake in Jasper Park, Alberta, and found the copepod *Canthocampus* to be the most abundant item, followed closely by Chironomidae.

The numerous accounts of food taken by the white sucker, *C. commersonni* (Simon, 1946, Couey, 1935, and others) indicate that this species utilizes molluscs, midges and other insect larvae, and the various entomostacans in lakes. According to these reports the food of the white sucker consists mostly of bottom forms including much detritus, but often plankton and the more pelagic insects were included.

The kinds, percentage of occurrence, and estimated percentage of volume of food of suckers taken in streams tributary to Yellowstone Lake are given in Table 1. Of 74 stomachs with food, 69 percent contained algae which constituted about one-third of the volume of all items. Pieces of higher aquatic

TABLE 1.—Percentage frequency of occurrence and estimated percentage of total volume of food items eaten by the longnose sucker in tributaries of Yellowstone Lake

Item	Unnamed tributary of West Thumb	Pelican Creek	Pelican Creek (Trap)			
Details concerning samples studied						
Dates of collection...	June, 1952	Aug. 20-Sept. 7, 1951	July 1-30, 1951-52			
Number of stomachs...	35	24	50			
Number with food...	34	19	21			
Range of total lengths of suckers examined	3.6-8.4	3.3-7.1	12.2-19.5			
Percentage of occurrence and of volume of food items						
Food organism	Occurrence	Volume	Occurrence	Volume	Occurrence	Volume
Algae.....	97	43	68	35	24	12
Higher aquatic plants.....	80	22	5	Tr. ¹	5	Tr.
Mollusca.....	3	Tr.	..	..	..	..
Ephemeroptera.....	6	1	42	19	86	48
Coleoptera.....	34	3	32	9	24	5
Trichoptera.....	9	2	37	9	38	11
Diptera.....	74	20	37	7	38	7
Arachnoidea.....	11	Tr.	..	..	..	..
Unidentified and debris.....	74	9	100	21	81	17

¹ Tr. = trace

plants occurred in 40 percent of the stomachs and composed about 10 percent of the volume. The orders of aquatic insects found included Ephemeroptera, Coleoptera, Trichoptera and Diptera. Their percentages of occurrence in all stomachs were 38, 31, 25, and 55, respectively. A few stomachs contained snails, fingernail clams, and water mites but the volumes of these items were too small to estimate. Debris and unidentified plant

and animal remains were found in 80 percent of the stomachs. The volume of this material made up about 15 percent of the total. There was no marked difference between the kinds and abundance of items found in the small and the large fish, except that the larger specimens more frequently contained Ephemeroptera and Trichoptera larvae.

Five of the eight specimens collected in the lake contained food in their stomachs. Crustacea (*Gammarus* and *Daphnia*) was the most important item with Diptera (Chironomidae) being a close second. The only other identifiable item was a few Ephemeroptera. The bottom and plankton crustaceans were probably very important in the diets of suckers feeding in the lake, while aquatic insects were the most important animal foods in the streams.

The high incidence and volume of algae and higher aquatic plants is convincing evidence that these are important in the diet of this species. There is insufficient evidence from this study to show that the sucker is an important food competitor of trout although a certain amount of competition is evident.

SPAWNING RUNS OF PELICAN CREEK

There is a definite run of suckers from the lake into the tributary streams at the time of spawning. According to Mr. Dunn, this run usually begins in late June in Pelican Creek and continues through most of July. The early part of this run coincides with the latter part of the cutthroat-trout run. In 1951, the first suckers were noticed on June 15, and approximately 300 entered the fish traps during June 16-18. Only a few entered the traps on June 19 and 20. This reduction is believed to have resulted from a change in the weather (warm and clear for several days prior to June 19 with a sudden change to wet and cold). There is evidence to show that sucker movement was influenced by water temperature changes (Fig. 1). Marked increases or decreases in water temperature were associated with similar increases or decreases in the number of fish that entered the trap. The sucker run was largely over by July 12 and consequently the increase in temperature following this date was not accompanied by an increase in the number of suckers. Dence (1948) showed that the spawning activity of the dwarf sucker *Catostomus commersonni utawana* was influenced by temperature.

Measurements were made on random samples of male and female suckers taken in the spawning runs of 1950 and 1951 (Fig. 2). The 365 males in these samples ranged in total length from 10.6 to 17.9 inches with an average of 14.0. Their weight ranged from 0.31 to 2.25 pounds with an average of 1.18. The 342 females varied in length from 13.6 to 20.1 inches with an average of 17.0 inches. Their weight ranged from 1.19 to 3.16 pounds with an average of 2.07. The average size of the females was significantly larger than the males.

An attempt was made to determine the length of time spawning suckers remained in Pelican Creek. A total of 328 (277 males, 51 females) upstream migrants was tagged in 1951 at the Pelican Creek trap with Peter-

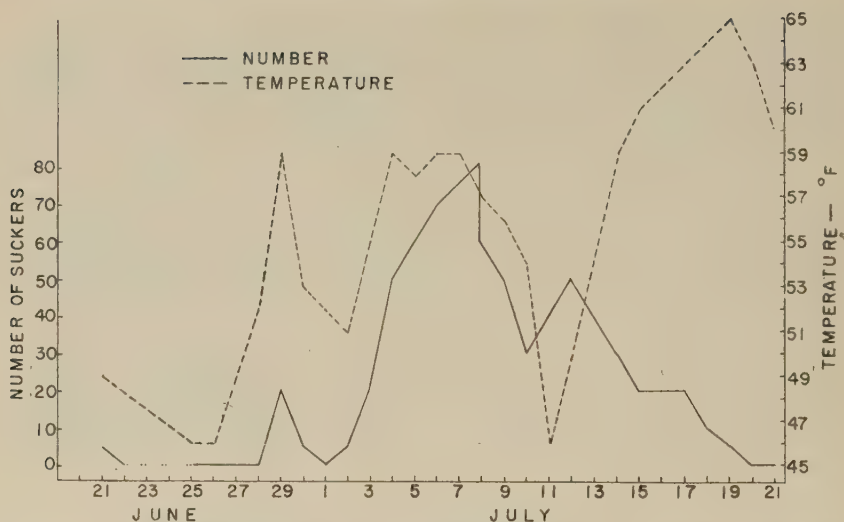


FIGURE 1.—Relationship between water temperatures and the number of longnose suckers observed each day of the 1951 season at Pelican Creek traps.

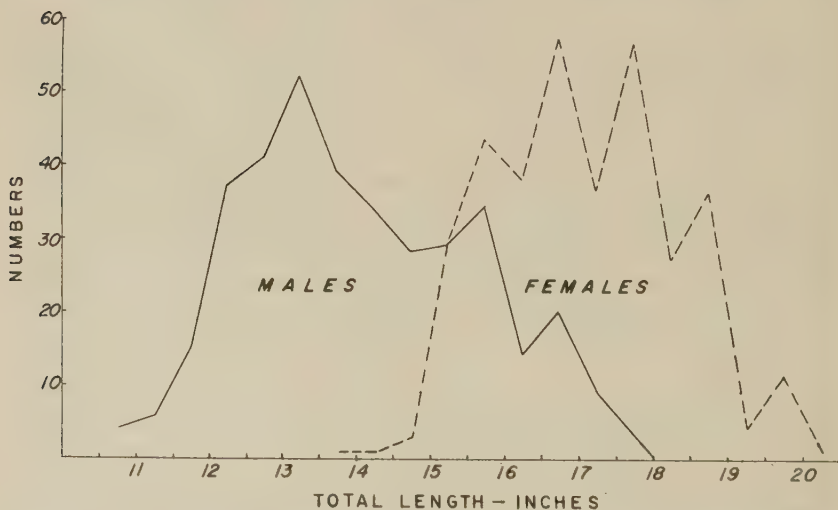


FIGURE 2.—Total lengths of male and female longnose suckers in the spawning runs of Pelican Creek, 1950 and 1951.

son disc tags. This project was seriously handicapped by a limitation imposed by the Park Service on the number of females which could be released. Their policy is to destroy all suckers that are captured.

A total of 17 tagged suckers (11 males and 6 females) returned to the traps on their way back to the lake. The time between release and recovery ranged from 14 to 25 days (average 19 days) for the females and from 5 to 39 days (average 17 days) for the males.

The fish were weighed at the time of tagging and again upon recovery. The loss of weight for nine males varied between 0.5 and 4.5 ounces (1.8 average) while the females' loss of weight varied from 3.0 to 6.5 ounces (4.7 average). It is not known whether this loss of weight was due entirely to spawning or in part to the irritation caused by the Peterson discs which were placed in the region below the dorsal fin.

Random samples of suckers comprising 253 males and 222 females from the spawning runs of 1950 and 1951 were aged (Table 2). This information indicates that male suckers rarely spawn before they are four years old, and females do not become sexually mature before they are five. Most of

TABLE 2.—Age composition of 253 male and 222 female suckers from the spawning runs at Pelican Creek, 1950 and 1951
[Roman numerals indicate number of completed annuli]

Item	Sex	Age group					
		III	IV	V	VI	VII	VIII
Number	Males	1	50	130	64	8	...
	Females	...	1	33	100	82	6
Percentage	Males	0.4	19.7	51.4	25.3	3.2	...
	Females	...	0.5	14.9	45.0	36.9	2.7

the males (51.4 percent) were in the five-year group while the majority of the females (45.0 percent) were in the six-year class. Eight males and 82 females were in the seven-year group, and six females and no males were eight years old. These data indicate that males mature a year younger than females and that the latter live to be older (at least those that appeared in the runs were older).

FRY AND FINGERLINGS

The first sucker fry observed in the summer of 1951 were taken on July 9 when vast numbers were found near the banks of Yellowstone River, about 300 yards below the lake. These fishes were confined to the quieter water harboring aquatic vegetation. They ranged in total length from 11 to 15 millimeters with an average of 13 millimeters. Another sample of young was taken at this same place on September 7, and these specimens ranged in length from 19 to 30 millimeters (average 23.5). On October 11, a collection of small fingerlings was taken from Pelican Creek less than a mile from its mouth. These suckers had an average length of 30.5 millimeters with a range of 25–38 millimeters.

The smallest fish known to have scales was 38 millimeters in total length. It is suspected that because of the small size of some of these young suckers,

they may go through their first winter in Yellowstone Lake without scales as was found to be true of some cutthroat trout (Brown and Bailey, 1952).

AGE AND GROWTH

The age and growth of the longnose sucker in Yellowstone Lake were based on 525 specimens (253 males, 222 females taken 1950, 1951 in Pelican Creek trap, and 50 immature specimens taken 1951, 1952 from Pelican Creek and unnamed tributary of West Thumb). These individuals ranged in total length from 3.3 to 19.7 inches, and represented all of the age groups from one to eight inclusive. Ages were determined by counting the annuli on the scales. Because of an obvious difference between the growth of males and females the results were tabulated separately (Table 3).

The average calculated total length at each annulus shows the males to be consistently smaller than the females. The difference is small in each of the first four years of life (0.1–0.4 inch) but is approximately one inch in each of the next three years. It is not known whether fish less than one year old show a differential in growth between the sexes.

Kathrein (1951) studied the growth of the longnose sucker from the Missouri River in Montana. He did not calculate the growth of males and females separately. A comparison between his data for the sexes combined (first figure) and those from Yellowstone Lake (second figure) is as follows: first year of life—3.0 and 2.0; second—5.5 and 4.8; third—8.1 and 8.5; fourth—10.4 and 11.7; fifth—12.3 and 13.6; sixth—13.7 and 15.8; seventh—14.7 and 17.4; eighth—15.5 and 18.1. The Missouri River specimens grew more rapidly than those from Yellowstone Lake during their first year of life. Thereafter the latter grew more rapidly and by the third year exceeded the Missouri specimens in total length. It is interesting to note that suckers of this species had a maximum age of eight years in both the Yellowstone and Missouri River samples. Clemens (1939) reported two *C. catostomus* from Okanagan Lake, where they were probably introduced, to be 11 3/8 and 16 1/2 inches in length, and apparently in their fourth and fifth summers respectively.

From the available information on the growth of this species, it is safe to conclude that the longnose sucker grows at an average rate or better in Yellowstone Lake.

DISTRIBUTION

A tagging project to determine the movement and distribution of suckers was initiated in 1951. This experiment failed because of certain administrative restrictions already mentioned. A total of 403 suckers (306 males and 97 females) was tagged at the traps in Pelican Creek in that year. This includes the 328 upstream migrants plus 75 downstream migrants. Of these, 74 have been accounted for as follows: 41 tagged fish were found dead on the Pelican Creek traps; 23 were found in pelican droppings on Molly Island which supports a rookery of these birds; 10 have been recov-

TABLE 3.—Average calculated total lengths (inches) of longnose suckers collected in 1950-51-52 from Yellowstone Lake and tributaries
[M = male; F = female]

Age group	Number		Average total length (inches) at capture		Year of life											
					1		2		3		4		5		6	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
I	144		14.7		12.2											
II	1	6	17.2		11.8		15.4									
III					3.3		7.5									
IV	50	1	10.6		2.2	2.8	5.9	7.3	9.7	10.5	12.2	14.3				
V	130	33	12.3	15.2	1.8	2.1	4.4	5.3	8.3	8.9	11.3	12.0	13.3	14.5		
VI	64	100	13.4	15.6	1.8	2.1	4.4	5.0	8.0	8.8	11.3	12.0	13.7	14.4	15.0	16.1
VII	8	82	15.3	16.7	1.7	1.9	4.1	4.5	7.5	10.8	11.9	13.3	14.3	15.1	16.2	17.5
VIII		6	16.4	17.7	1.7	1.7	...	4.5	8.1	...	...	11.3	...	13.7	...	15.4
			18.2		...											16.9
																18.1
Grand averages (by sex)	253	222	...	...	1.9	2.0	4.7	4.9	8.4	8.7	11.5	11.9	13.4	14.4	15.0	16.1
Grand averages (all fish)	525		...	...	2.0		4.8		8.5		11.7		13.6		15.8	

¹ Immature fish — not sexed and not included in totals or averages of males and females but included in the grand averages of all fish.

ered by fishermen in the area between Fishing Bridge and the mouth of Pelican Creek. The large number of suckers taken by pelicans is not very significant when it is known that many of these fish were in a very weakened condition as a result of being retained in the fish traps before their release.

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FISH POPULATIONS IN ALABAMA RIVERS AND IMPOUNDMENTS

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ABSTRACT

Fish populations in large Alabama rivers and large impoundments were sampled by using emulsifiable rotenone at a concentration of 1 p.p.m. which is applied to measured areas with pumps and hose. Large channel, blue, and flathead catfishes appeared to be the principal piscivorous species in rivers. The ratios of the weight of forage fish to piscivorous fish and the percentages by weight of harvestable fish in the entire populations appeared similar to those in pond fish populations. The change of environment following impoundment of rivers caused large changes in the species composition of the stock. Pollution of rivers produced changes from balanced to unbalanced fish populations. In one river a polluted area had a smaller standing crop than did an unpolluted portion of the same river, while in another, the polluted area had the larger stock.

INTRODUCTION

The species composition and abundance of fish populations in large rivers is not well known. The need for knowledge about the dynamics of river populations is becoming increasingly important as a basis for proper management of this great resource and because river populations furnish the stock of fishes for large impoundments.

Within the last 30 years many large reservoirs have been constructed on rivers throughout the United States for power production, navigation, irrigation, and flood control. The future will bring a tremendous increase in the number of large impoundments containing thousands of new acres of fishing waters that will require management. River populations furnish the original stock of fishes that become the impoundment populations. The similarities and differences between the river and impoundment populations have not been studied sufficiently to understand the changes which occur in the population after impoundment.

Despite considerable literature on the pollution of rivers, practically nothing has been published on the actual effect of pollution on river populations, except when fish were killed outright. If only one or two species are affected, pollution may be difficult to detect and even more difficult to evaluate because so little is understood about the interrelationships between species in the total population.

Studies on fish populations of ponds have resulted in a better understanding of the factors affecting balance and harvest, the predator-prey

relationships, and other factors (Swingle, 1950). The immediate goal of the present work was to learn whether relationships in river and impoundment populations are similar to those in ponds. The changes in populations that have taken place when rivers expanded into impoundments will be described, and some observations on the effect of pollution on river populations are included. These studies were made cooperatively with the Alabama State Department of Conservation.

METHODS

Sampling methods on rivers.—In spite of the many faults of rotenone sampling, it appeared to be the most suitable for studying the populations of large rivers. The methods were modified from the one employed by Scott (1951) on the Coosa River in Alabama. An area of 1 or 2 acres extending from the bank to the middle of the river was marked off with floats. Emulsifiable rotenone (5 percent) was then applied at the rate of 1 p.p.m. with pumps which forced the rotenone through a hose to the desired depth. At first the hose was raised and lowered during application to spread the poison more uniformly through the water. Later, the rotenone was forced through irrigation hose, perforated at intervals throughout its length.

At the start of the operation a line of poison was applied to the downstream edge of the area to be sampled. This application was not sufficiently heavy to kill fish but was used to cause the fish downstream to move out of the way of heavier waves of poison that were to follow. The effectiveness of this "warning line" was not studied. The poison was then applied in repeated heavy curtains at the upstream edge of the sample area, and was carried over the area by the current.

The poisoned fish began to appear at the surface in the sampled area within a few minutes and were collected as they drifted downstream with the current. Recoveries were made using a fleet of 10 to 12 boats, some of which were equipped with a scoop 8 feet wide, which made it possible to pick up the small inactive fish rapidly. In other boats dip nets were used to recover both large and small fish. The fish were then separated by species and by inch-groups and weighed.

Sampling large impoundments.—Two types of areas were sampled in large impoundments—cove areas with quiet, relatively shallow waters, and deep, open-water areas. In both situations emulsifiable rotenone was applied at the rate of 1 p.p.m. by pumps and hoses.

The cove areas of 1 to 3 acres were sampled by establishing a curtain of poison across the open end and applying the poison in lines 15 to 20 feet apart, working from the outer line into the cove. The area was then stirred with an outboard motor and the fish were picked up as they appeared at the surface during a 2-day period. The coves were accurately surveyed to determine their area.

The open-water sample area, 1 to 2 acres in size, extended from the bank into the deep water. The maximum depth was 40 feet. The area was marked off with anchored floats and the poison applied with pumps and hoses from top to bottom in successive curtains about 20 feet apart, starting along the outer margins and working toward the center.

RESULTS AND DISCUSSION

Factors affecting accuracy of results.—Many of the inaccuracies due to rotenone sampling are well known. All the fish affected by the poison are not recovered. In rivers especially, varying numbers of large fishes evaded capture and relatively few dead fish were found on the second day. To a lesser degree, the same error occurred in open-water impoundment samples. Also, capture of small fishes up to and including the 2-inch group was difficult and inadequate.

Fish from outside the sample area also are killed to a greater or less extent, either by their movement into the poisoned area or by movement of the masses of poisoned waters into new locations. In the rivers especially, the lethal block of water moved rapidly downstream, carrying with it those fishes from the sample area which were rendered inactive. Undoubtedly, other fish which failed to move away from the first warning line of poison as it passed downstream were also killed by the rotenone. Fish were usually picked up for distances of 1 to 5 miles below the sample area. Where there was no doubt that the moving block of rotenone was killing far outside the sample area, those fish known to originate outside the area were not included in the population reported. The sample of fish collected in rivers and in the open-water impoundment samples may also be expected to include a disproportionate amount of the more susceptible species.

Further critical studies are obviously needed on the rotenone method of sampling to determine the extent of the sampling error. The various factors affecting the movement and dissipation of the poisoned water also need investigation. As used, however, it has yielded the following information on population characteristics: the species composition of river populations, the approximate pounds of fish per acre, the changes taking place following impoundment, and some effects of pollution on the fish populations.

Analysis of data.—In the treatment of the data, indices have been used that have been helpful in interpreting the results of earlier studies of fish populations in this area (Swingle, 1950). Of primary importance, of course, is the standing crop in pounds per acre. Also valuable in defining the status of populations are the A_T value—percentage by weight of harvestable fish in the total population (see Table 1 for the minimum sizes at which different species are judged to become "harvestable"); the F/C ratio—the ratio of the total weights of forage species (F) to piscivorous species (C); and the E value—percentage by weight of the different species in the total population. The A_T , F/C, and E values are ratios by which populations can be compared. Whole populations need not be accurately measured, but a large adequate sample is required.

Pounds of fish per acre.—The rotenone method of sampling gave relatively good population samples and the pounds of fish recovered corresponded rather closely to those obtained in similar waters in which sampling problems were less difficult. For example, in the Black Warrior River (Table 2) where sewage produced a plankton bloom equal to that of a highly fertilized pond, 1,069.9 pounds of fish were recovered per acre of sample area. The standing crop of a fertilized pond at Auburn with bluegills

TABLE 1.—Minimum harvestable sizes of fishes used in computing AT values

Common name	Scientific name	Weight pounds	Approximate total length (inches)
Largemouth bass.....	<i>Micropterus salmoides</i>	0.4	10
Spotted bass.....	<i>Micropterus punctulatus</i>	0.4	9
White bass.....	<i>Morone chrysops</i>	0.3	9
Walleye.....	<i>Stizostedion v. vitreum</i>	0.5	12
Chain pickerel.....	<i>Esox niger</i>	0.7	16
Longnose gar.....	<i>Lepisosteus osseus</i>	1.0	20
Spotted gar.....	<i>Lepisosteus productus</i>	1.0	17
Crappies.....	<i>Pomoxis</i> spp.....	0.26	8
Sunfishes.....	<i>Lepomis</i> spp.....	0.1	6
Channel catfish.....	<i>Ictalurus punctatus</i>	0.3	10
Blue catfish.....	<i>Ictalurus furcatus</i>	0.3	10
Flathead catfish.....	<i>Pilodictis olivaris</i>	0.5	12
Freshwater drum.....	<i>Aplodinotus grunniens</i>	0.3	9
Carp.....	<i>Cyprinus carpio</i>	1.0	13
Buffalo.....	<i>Ichtiobus</i> sp; <i>Megastomalobus</i> sp.....	1.0	13
Paddlefish.....	<i>Polyodon spathula</i>	1.0	23
Skipjack.....	<i>Pomolobus chrysochloris</i>	0.5	12
Mooneye.....	<i>Hiodon tergisus</i>	0.5	12
Gizzard shad.....	<i>Dorosoma cepedianum</i>	0.5	11
Spotted sucker.....	<i>Minytrema melanops</i>	0.5	11
Redhorse sucker.....	<i>Moxostoma</i> spp.....	0.5	11
Carp sucker.....	<i>Carpoides</i> sp.....	0.5	10
American eel.....	<i>Anguilla bostoniensis</i>	0.5	19

plus largemouth bass and gizzard shad, was 1,079.6 pounds fish per acre, where the results were obtained by draining the pond.

In the lower coastal area, the Tensaw River was found to carry 1,544.6 pounds of fish per acre. The reason for this high poundage is not known. It may be due in part to a higher accumulated fertility, to production over a wide flood plain during part of the year, or to kill by rotenone over a longer period or over an area greater than the sample area. The poisoned mass of water in the sample area was shifted alternately up- and downstream by the tides.

The approximate pounds of fish per acre in the Tallapoosa River was 45.7, (Table 3) and the figures for the downstream impoundment, Lake Martin, were 26.7 and 31.4 in cove areas and 24.0 in deep, open water. These values are similar to the figure of 40 pounds per acre obtained by draining ponds in similar areas of low fertility in Alabama (Swingle and Smith, 1947).

The Coosa River carried 137.4 pounds of fish per acre in shallow, swift areas and 128.0 pounds in deep water, while the first impoundment downstream, Lay Lake, supported 144.4 pounds per acre in a cove area and 60.9 pounds in deep, open water (Table 3). Jordan Reservoir, the third downstream impoundment on the same river yielded 146.4 pounds per acre in a cove area and 482.3 pounds per acre in deep, open water. The relatively good agreement among the standing crops in these rivers and in impoundments on the same rivers gives added confidence in the results.

The figures on pounds of fish per acre obtained by rotenone sampling apparently may be considered usable approximations of the standing

TABLE 2.—*Approximate pounds of fish per acre and population values¹ in large Alabama rivers*

Rivers	Area sampled (acres)	Type of area	Water depth		Pounds of fish per acre	F/C, when C group includes catfishes with minimum total lengths of			Ar
			Maximum (feet)	Average (feet)		12 inches	14 inches	16 inches	
Coosa.....	1.5	Deep	40	25	128.0	1.4	.....	.....	84.4
Coosa.....	2.0	Shallow	10	8	137.4	6.2	.....	.....	86.0
Coosa.....	2.0	Deep unpolluted	15	9	85.6	0.8	1.2	2.4	82.6
Coosa.....	2.0	Deep polluted	18	15	8.3	16.2	62.7	62.7	11.7
Tombigbee.....	2.0	Cutoff	15	12	1,859.4	27.6	7.9	28.4	30.5
Tombigbee.....	1.0	Deep	30	25	408.3	0.6	0.8	1.0	72.0
Tombigbee.....	2.0	Shallow	18	15	527.8	0.5	0.6	0.7	89.0
Black Warrior.....	1.0	Deep polluted	20	15	1,069.9	11.9	15.6	21.2	27.9
Tallapoosa.....	2.0	Deep	10	8	45.7	2.4	5.3	9.2	70.5
Tensaw.....	2.0	Deep	25	20	1,544.6	1.2	1.6	2.1	81.5

¹ F/C=ratio of the weight of forage fish to piscivorous fishA_T=percentage by weight of harvestable fish in the total population

TABLE 3.—Percentage species composition by weight (*E. values*) in two Alabama rivers and in large impoundments on these rivers

Place and year of sample	Area sampled (acres)	Type of area	Pounds per acre	E values of principal species														
				Blue catfish	Chan- nel head catfish	Flat- head catfish	Fresh- water drum	Buffalo shad	Giz- zard shad	Thread- fin shad ¹	Large- mouth bass	Spot- ted bass	White bass	Blue- gill ²	Suck- ers	Carp	Crap- pies	
Coosa river and impoundments																		
River proper 1950	2.0 1.5	Shallow, swift Deep	137.4 128.0	0.5 26.9	7.0 9.3	3.8 13.9	74.2 33.8	 10.3	0.3 1.5	.... ....	.... ....	3.9 0.9	0.6 30.0	0.4 ....	.... ....	.... ....	.... ....	
Lay Reservoir 1950	3.0 3.0	Cove Deep, open water	144.4 60.9	2.5 19.7	3.7 12.7	1.8 4.2	2.7 6.0	2.8 5.5	58.3 28.4	.... ....	4.8 3.7	0.3 3.2	 1.6	14.5 2.6	3.7 1.6	.... ....	1.1 3.3	
Jordan Reservoir 1952	3.2 2.0	Cove Deep, open water	146.4 482.3	4.2 2.7	4.3 1.5	0.3 0.5	0.1 12.8	10.9 16.5	44.4 27.9	 0.6	9.5 4.7	2.2 2.7	1.0 19.0	6.8 4.5	1.3 ....	.... ....	0.1 1.3	
Tallapoosa river and impoundments																		
River proper 1951	2.0	Deep	45.7		27.1	16.4						3.5	2.1	1.3	3.7	2.1	38.1	
Lake Martin 1951	3.0 1.0	Cove Deep, open	26.7 24.0		22.4 11.4	30.0 0.1						14.4 3.3	17.7 25.0	0.1 9.6	38.0 39.5			0.8
Lake Martin 1949	3.0	Cove	31.4		13.6	1.2						3.0	21.6		11.9	4.1	4.1	1.9

¹ *Signalosa heltenensis*² *Lepomis macrochirus*³ Less than 0.05 per cent

crop, subject to revision as better methods of sampling become available.

*Percentage of harvestable fish (A_T).—*The A_T value, the percentage by weight of the harvestable fishes, is a measure of the efficiency of a population. In pond populations, values below 40 indicate unsatisfactory balance and those below 33 indicate unbalanced fish populations (Swingle, 1950).

In general, the A_T values in rivers (Table 2) are similar to those in pond populations. While low efficiency in recovery of the small fish in river populations constituted a serious error in rotenone sampling, their combined weight was sufficiently small that the loss had little effect upon the A_T values. In normal rivers (Table 2) the values ranged from 70.5 to 89.0, which in pond populations would indicate a very desirable balance between species. However, A_T values indicating unbalance were found in polluted areas of the Coosa and the Black Warrior and in an unpolluted cutoff area of the Tombigbee River. Unbalance, caused by these environmental conditions, resulted in populations incapable of producing satisfactory yearly crops of harvestable fish.

*Ratio of forage fish to piscivorous species (F/C).—*In calculating the F/C ratios (ratio of the weight of forage to piscivorous fish), it immediately became evident either that the relationships typical of ponds did not hold in rivers or that different piscivorous (C) species were involved. Studies at Auburn, together with unreported work by Dequine in Florida and Dickson in Georgia, indicated that the large catfishes (channel, blue, and flathead), were probably the principal C species in rivers. Dequine (private communication) found that all channel catfish 14 inches long or larger fed principally upon fishes. Alabama investigations, though still incomplete, indicated that catfishes 16 inches or larger were probably the principal C species of rivers. Because of uncertainty as to the length at which catfishes became primarily piscivorous, the F/C ratios given in Table 2 were calculated, with 12, 14, and 16 inches as the boundaries above which these catfishes were classified as C species.

The role of the catfishes in river and impoundment populations needs further study. If their classification as C species is valid, the F/C ratios in rivers and impoundments then appear closely similar to those in pond populations and may be useful in comparing various types of populations. The F/C ratios given in subsequent discussions are based on the 16-inch limit.

*Percentage species composition in rivers (E values).—*The E value of a species, or percentage of the weight of a particular species in the total population, was originally called the survival efficiency of that species (Swingle, 1950). It would appear preferable to call it the environmental value of a species. E values of the principal species in certain Alabama rivers are given in Table 4 and those in other rivers and their impoundments in Table 3.

Sport fishes were of minor importance in large rivers, since they seldom made up 5 percent of the total population. River populations were composed principally of blue catfish, channel catfish, flathead catfish, freshwater drum, and buffalo.

Freshwater drum preferred swift-water areas in the rivers. Blue catfish,

channel catfish and buffalo preferred the deeper and quieter waters. Gizzard shad was a minor species in rapidly moving waters, but became a major species in quiet waters above navigation lock dams on the Black Warrior and in cutoffs of the Tombigbee River. The carp was absent in the deeper, swifter rivers, but was a major species in the shallow, muddy waters of the Tallapoosa River.

Changes following impoundment of rivers.—Three impoundments have been constructed on the Coosa River by the Alabama Power Company for the production of electricity. The upstream reservoir, Lay Lake, constructed in 1914, has an area of 6,700 acres. Immediately downstream are Mitchell Lake built in 1922 with an area of 5,800 acres, and Jordan Lake constructed in 1928 with an area of 4,900 acres. A comparison of the fish populations now present in Lay and Jordan lakes with those in the Coosa River above the lakes indicated certain major changes following impoundment (Table 3).

Gizzard shad, a quiet-water species with E values of 0.3 and 1.5 in the river population, composed from 27.9 to 58.3 percent of the impoundment populations. It was more abundant in quiet coves than in the open-water areas.

The abundance of freshwater drum, on the contrary, decreased following impoundment. The E values were 33.8 and 74.2 in the river population but only from 0.1 to 12.8 in the impoundments. It was more abundant in deep, open waters than in the cove areas. The catfishes decreased slightly in relative abundance in Lay Lake, the upstream reservoir, and decreased greatly in Jordan, the downstream reservoir. This difference may possibly indicate that flowing water is necessary for adequate reproduction.

The effect of impoundment upon game fishes varied from species to species. Largemouth bass, one of the most desirable sport and predatory species, was absent from the Coosa River populations, but was probably present in the quieter tributary waters. In the impoundments its E values varied from 3.7 to 9.5, being more abundant in coves than in open water. Spotted bass maintained themselves in the river and the reservoirs in approximately equal relative abundance. Bluegills, unimportant in the river, increased following impoundment, with E values of 2.6 to 14.5 in the reservoir populations. The crappies, important game species in many impoundments, were lacking in the river and made up only 0.1 to 3.3 percent of the impoundment populations.

Three power impoundments were also constructed on the Tallapoosa River by the Alabama Power Company. Population studies were made only in the river and in the upper reservoir, Lake Martin (Table 3). This lake was impounded in 1926 and has an area of 40,000 acres. Gizzard shad, blue catfish, and freshwater drum were not present in the Tallapoosa River nor were they found in Lake Martin. Since the gizzard shad is often considered to be a desirable forage species for large impoundments, it is of interest that in its absence the combined weight of principal predator game species (largemouth bass, spotted bass, white bass, and crappies) made up 24.6 to 27.9 percent of the population in Lake Martin; in the presence of gizzard

shad, these same species in the Coosa drainage made up only 6.2 and 11.8 percent of the Lay Lake population and from 12.8 to 27.7 percent of that in Jordan Lake.

The carp, already present in the river, became extremely abundant in Lake Martin immediately subsequent to impoundment. Gradually, it declined to a point where, 24 to 26 years later, very few are caught and it constitutes no more than 4.1 percent of the population.

Largemouth bass, with an E value of 3.5 in the river, varied from 3.0 to 14.4 percent of the impoundment population. Bluegills, with an E value of 3.7 in the river, made up 11.9 to 39.5 percent of the impoundment population.

Effect of pollution on river populations.—The effect of pollution on river populations in the Coosa River was determined by sampling in an unpolluted area above Gadsden, Alabama and in an area five miles below the point of release of industrial and domestic pollution. Analysis for pH, O₂ and CO₂ indicated generally satisfactory conditions in both areas. The fish populations, however, differed greatly (Table 2). In the unpolluted area the standing crop was 85.6 pounds per acre with an F/C ratio of 2.4 and an A_T value of 82.6, both desirable ratios. In the polluted area, the standing crop was 8.3 pounds of fish per acre, with an F/C ratio of 62.7 and A_T value of 11.7. These indicated both a great reduction in total pounds of fish per acre and a change to an unbalanced, unproductive population as a result of pollution.

The Black Warrior River was sampled 100 miles below the point where domestic pollution reduced the dissolved oxygen to less than 1 p.p.m. (Alabama Water Improvement Advisory Commission, 1949). At the point of sampling, chemical analyses indicated complete recovery of the river from pollution. There was 1,069.9 pounds of fish per acre, a great increase over the poundage in similar habitats in unpolluted rivers; the sewage was apparently exerting a fertilizing effect. Analysis of the population, however, yielded an F/C value of 21.2 and an A_T value of 27.9, both of which indicated an undesirable, unbalanced population, incapable of producing satisfactory yearly crops of harvestable fishes.

Chemical analyses alone are inadequate as a method of studying the effects of pollution in rivers. Masses of badly polluted water probably move far downstream at irregular intervals, causing changes in the fish population which are measurable by population values long after the river water returns to a normal condition. In some situations, therefore, the rotenone sampling method provides a more dependable measure of pollution than chemical analyses, and the damage to the fish population can be more directly evaluated. In both of the polluted river areas sampled, pollution had broken down the controls within the population over the number of fish present, transforming them into unbalanced populations. In one area this disruption of normal relations was accompanied by a reduction and in the other by a great increase in total pounds of fish per acre.

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GROWTH OF BLUEGILLS IN A NEW LAKE, WITH PARTICULAR REFERENCE TO FALSE ANNULI^{1 2}

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ABSTRACT

McFarland Pond was constructed in 1946 and stocked with 23 2-year-old bluegills (*Lepomis macrochirus*) in 1947. Scales from the 1947 to 1949 year classes of bluegills were studied with particular attention to the recognition of false and true annuli. No consistent changes in coefficient of condition, K , were noted except for a tendency for the K value to increase with increase in length of fish. Annulus formation occurred from mid-February to mid-June, with most fish forming annuli in the last half of May or early June. Although the body-scale relationship is better described by a third-degree equation, calculated lengths based upon a straight-line relationship were nearly as accurate. The brood stock grew rapidly when first placed in the lake. The 1947 year class grew less in 1947 than did the 1948 and 1949 young of the year during their first summers. Late spawning was probably the cause of the poor growth in 1947. By 1949, the bluegills were severely stunted and showed little growth after they reached 1 year of age. Most of the season's growth was completed by early July. The faster growing individuals disappeared before their third year. Male bluegills showed more rapid growth than females after the first year of life. About 90 percent of the 1948 and 1949 year class bluegills showed checks on their scales before the first annulus whereas only 10 percent of the 1947 year class bluegills showed such false marks. False marks after the first annulus seem to be connected with sexual activity. Suggestions are given for recognizing false annuli.

INTRODUCTION

Although the scale method has been widely used in the study of fish growth, there is still need for critical evaluation of the method. Misinterpretation of the scale markings may lead to erroneous conclusions. A special effort was made in the present study of age and growth of the bluegill to determine how false annuli might be more readily distinguished from true annuli. Although no rules for the recognition of false annuli can be given, it is believed that the experience and data presented here may be of value to other fishery biologists.

A population of bluegills in a new impoundment, McFarland Pond (R.

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23 W., T. 84 N., Sec. 7), Story County, Iowa, was selected for this study. The population originated from 23 2-year-old bluegills, ranging from 72 to 120 millimeters (2.8 to 4.7 inches) in total length, stocked in the pond on May 23, 1947. Scales were taken from 1,235 bluegills during the period May 1949 to July 1950.

McFarland Pond, a relatively rich artificial impoundment constructed in the fall of 1946, has a surface area of 7 acres and a maximum depth of 23 feet. Thermal stratification and subsurface stagnation were so pronounced that dissolved oxygen became severely depleted at depths of 2 meters or more during late winter and summer months of the period studied, limiting the normal activities of fish to the shallower strata (Sprugel, 1952).

Hoop nets, a "common-sense" minnow seine, basket traps, experimental gill nets, and angling were used in obtaining specimens. Total, fork, and standard lengths were measured to the nearest millimeter. Factors for converting standard to fork or total length measurements were calculated, sexes separately, for each 10-millimeter size group. No consistent sex-related differences in the relationships of these lengths were noted and the tendency (frequently observed in fishes) for the larger individuals to have the relatively shorter tails was weak. Accordingly the following conversion factors, based on 985 specimens, may be used without reference to sex or length of fish: standard to fork length, 1.217; standard to total length, 1.300; fork to total length, 1.068. Weights were recorded in grams.

The fish scales were removed from an area surrounding and including the point where the posterior tip of the extended left pectoral fin touched the second and third rows of scales below the lateral line when the fin was pressed against the body. After cleaning, the scales were mounted dry between microscope slides bound together at the ends with cellulose tape. This method proved to be a satisfactory and durable means of preparing scale mounts quickly. Only the larger scales needed to be moistened before study. The largest and best formed scales in each sample were examined on a microprojector at the magnification $\times 42.0$ diameters. Scales were read 4 times to eliminate inconsistencies. Fewer than 5 percent were rejected because of inability to interpret them with confidence.

LENGTH-WEIGHT RELATIONSHIP AND CONDITION

Data on the length-weight relationship of McFarland Pond bluegills (Table 1) are given in terms of total length in inches and weight in ounces and of standard length in millimeters and weight in grams. Included also are values of the coefficient of condition, K , which is a means of expressing the relative plumpness of a fish.

$$K = \frac{W \times 10^5}{L^3},$$

where

W = weight in grams, and

L = standard length in millimeters.

A progressive increase in K with increase in length beyond 40 millimeters

TABLE 1.—*Length-weight relationship and coefficient of condition, K, of McFarland Pond bluegills in 1949 and 1950*
(Based on a total of 981 fish. Length and weight averages are for 10-millimeter intervals of standard length)

Number of fish	Total length (inches)	Weight (ounces)	Standard length (millimeters)	Weight (grams)	K
180	2.3	0.11	46.0	3.1	3.16
272	2.9	0.20	55.0	5.6	3.37
187	3.3	0.30	63.1	8.5	3.39
130	3.8	0.49	74.5	14.0	3.38
106	4.2	0.71	84.0	20.2	3.41
67	4.8	1.07	93.9	30.5	3.66
23	5.2	1.47	103.4	42.0	3.82
7	5.6	2.04	113.1	58.4	4.05
3	6.2	3.21	124.6	91.6	4.73
1	6.5	3.50	132.0	100.0	4.35
3	8.6	11.23	176.6	318.3	6.11
2	9.2	11.02	186.5	312.5	4.82

was evident (Table 1). Preliminary tabulations (not given here) revealed no consistent difference in the condition coefficients of male and female bluegills but indicated that during May, June, and July the coefficients of condition for bluegills older than 1 year were higher than at other seasons, probably due to sexual development.

VALIDITY OF THE ANNULUS AS A YEAR-MARK

The scale method of determining age and growth of fish is the most widely used aging technique at the present time. Creaser (1926), Van Oosten (1929), and others have given excellent reviews of the literature on the scale method. Van Oosten (1929) and Hile (1941) listed criteria for testing the validity of annuli as year-marks. Creaser (1926) demonstrated the validity of the scale method for age determination of some fishes in the family Centrarchidae. Evidence that annuli indicate the bluegill's age was given by Beckman (1943) in his work on the formation of annuli on scales of certain Michigan fishes. Various investigators are not in complete agreement concerning the cause, time of formation, frequency of occurrence, or significance of scale marks.

The general validity of age determinations from scales is believed to be confirmed for McFarland Pond bluegills by the following observations most of which are treated in greater detail in later sections:

- a. In general, fish assigned to the same age group possessed similar lengths.
- b. Calculated lengths at the first annulus were similar for the fish that spent their first year in the pond but did not agree fully with those of the seed stock which had lived their earlier years in a different body of water.
- c. The observed lengths of 1947 year class specimens collected in October 1947 and April 1948 (27 and 37 millimeters respectively) agreed closely with the calculated first-year lengths of individuals of the same year class collected in 1949 and 1950.
- d. No bluegills of age-group III could have been in the pond in 1949 and no scales from fish collected in that period exhibited 3 true annuli.
- e. First-year accessory scale marks (false annuli laid down prior to the formation of the first annulus) were present consistently in either a high or a low percentage of specimens from a year class, indicating that the production of false marks was caused by some unknown factors affecting the whole population of young fish. The low incidence of first-year accessory marks was characteristic of the 1947 year class. These marks were present on 10.2 percent of the specimens with 2 annuli collected in June and July of 1949, and on 22.2 percent of the individuals with 3 annuli taken during the same months in 1950.
- f. Annuli were formed at approximately the same time in each of the two seasons observed.
- g. Calculated growth beyond the last annulus increased during the summer months (Table 8). This increase was somewhat irregular in some years when growth was slow but always it indicated the formation of true annuli to be annual.

TIME OF ANNULUS FORMATION

Bennett, Thompson, and Parr (1940) reported that the annuli formed on the scales of some yearling bluegills in Fork Lake, Illinois, before the middle of April, and that annulus formation of all yearling bluegills was completed by the end of May. Ricker (1942) stated that annuli were laid down on

bluegill scales in lakes of northern Indiana at least from February to June, and that the majority formed in May. Beckman (1943) found that the annulus was formed between April 23 and 29 in his 1939 collections of yearling bluegills from Pasinski Pond in south-central Michigan. He concluded that the annuli were completed rapidly in Michigan lakes but that the time of annulus formation was progressively later from south to north. Burress, working with fish of known age in Missouri ponds, noted new annulus formation by bluegills in one pond as early as February 22, in two other ponds by late March, and in a fourth pond by early April.⁴ He believed that poor food conditions might be responsible for the later annulus formation in some ponds.

TABLE 2.—*Period of annulus formation in McFarland Pond bluegills*
[Number of specimens in parentheses]

Date of collection	Water temperature, surface to bottom (F.°)	Percentage of fish with a newly completed annulus in age group			
		I	II	III	IV
1949					
May 1-2.....	.....	37.5 (56)	68.4 (19)	.....	.....
June 3-13.....	76-48	100.0 (32)	100.0 (54)	.....	.....
do. 21-28 ¹	82-50	100.0 (19)	100.0 (23)	.....	100.0 (4)
1950					
Feb. 4-10.....	33-39	0.0 (1)	7.6 (13)	0.0 (1)	.....
do. 17-24 ²	33-38	.....	0.0 (9)	.....	.....
Mar. 7-9.....	33-39	0.0 (1)	.....	.....	.....
do. 16-31.....	34-40	0.0 (5)	0.0 (29)	0.0 (6)	.....
Apr. 4-10.....	42-41	2.6 (77)	6.6 (76)	0.0 (44)	.....
do. 17-24.....	48-42	8.3 (12)	15.8 (39)	0.0 (2)	.....
May 1-12.....	60-48	9.0 (11)	38.2 (34)	0.0 (3)	.....
do. 15-30.....	72-49	25.0 (12)	74.5 (47)	7.7 (13)	.....
June 5-7.....	70-50	100.0 (17)	90.9 (33)	42.9 (7)	.....
do. 19-28 ¹	70-56	100.0 (20)	100.0 (26)	100.0 (7)	.....
July 7.....	71-56	100.0 (9)	100.0 (18)	100.0 (13)	.....

¹ All fish of all ages collected later in the season had completed annuli

² Ice covered the pond until March 2

New annuli were being formed in some McFarland Pond bluegills, May 1, when collections were initiated in 1949, and annulus formation was completed by the first week in June (Table 2). The first specimen whose scales exhibited a newly formed annulus in 1950 was a II-group male taken from the ice-covered pond on February 10. Although the development of annuli on scales of bluegills of age-groups I and II began to appear in collections made during the first week in April, no specimens of the III-group showed current-year marks until mid-May. All bluegills had completed annulus production by mid-June. The majority of the individuals in age-group I formed year-marks during the last 2 weeks in May but most of the III-group specimens accomplished the same thing in the first 2 weeks in June. There was no consistent relationship within an age group between the size

⁴ Burress, Ralph M. 1949. The growth rates of bluegills and largemouth black bass in fertilized and unfertilized ponds in central Missouri. Unpublished M. Sc. thesis, University of Missouri.

of the individual and the time at which the annulus was formed. There was also no definite relationship between either coefficient of condition or feeding activity, as evidenced by presence of food in stomachs, and the time of annulus formation. Earlier annular development in 1949 appeared to be roughly correlated with earlier increase in water temperature (Table 2). This correlation does not represent a clear-cut, inflexible relationship since variation within and between age groups in a given season may be marked.

BODY-SCALE RELATIONSHIP

Bennett, Thompson, and Parr (1940) described the body-scale relationship of bluegills in Fork Lake, Illinois, by means of a smoothed curve which intersected the axis of total length at 22 millimeters. Ricker (1942) developed a straight line with an intercept of 20 millimeters fork length in a graph of the relationship between anterior scale radius and fish length in bluegills from northern Indiana lakes. Lewis (1950) determined that the body-scale relationship for 203 Red Haw Lake bluegills in southern Iowa was represented by a straight line with an intercept of 13.0 millimeters standard length.

In this study of 1,019 McFarland Pond bluegills, the body-scale (L/Sc) ratio decreased as standard length increased (Table 3); that is, the rela-

TABLE 3.—*Relationship between body length (L) and magnified ($\times 42.0$) scale radius (Sc) of McFarland Pond bluegills*

[The data are averages for 10-millimeter intervals, standard length]

Number of fish	Standard length (millimeters)	Magnified scale radius (millimeters)	L/Sc	Number of fish	Standard length (millimeters)	Magnified scale radius (millimeters)	L/Sc
1	18.5	10.0	1.85	106	84.0	87.1	0.96
7	25.5	17.8	1.43	67	93.9	98.1	0.96
30	34.7	27.4	1.27	23	103.4	108.0	0.96
180	46.1	41.1	1.12	7	113.1	119.4	0.95
272	55.0	53.2	1.03	4	126.5	133.3	0.95
187	63.1	63.9	0.93	...	.....	.....	.....
130	74.5	75.8	0.92	5	180.6	190.2	0.95

tive size of the scales increased with increase in length of fish. A slight deviation from this tendency (that could have resulted from sampling error) was noted in specimens over 110 millimeters long. No consistent sex differences were evident in the body-scale relationship. The L/Sc ratios for specimens in each 10-millimeter size group were also calculated and arranged according to time of collection but no consistent trends were observed.

The data on standard length and scale radius (Table 3) were plotted and fitted (Figure 1) with a linear regression line represented by the equation:

$$L = 8.41 + 0.88712 S,$$

where
and

L = standard length in millimeters,

S = anterior scale radius ($\times 42$) in millimeters.

Greatest deviations from the fitted line occurred at the extreme body

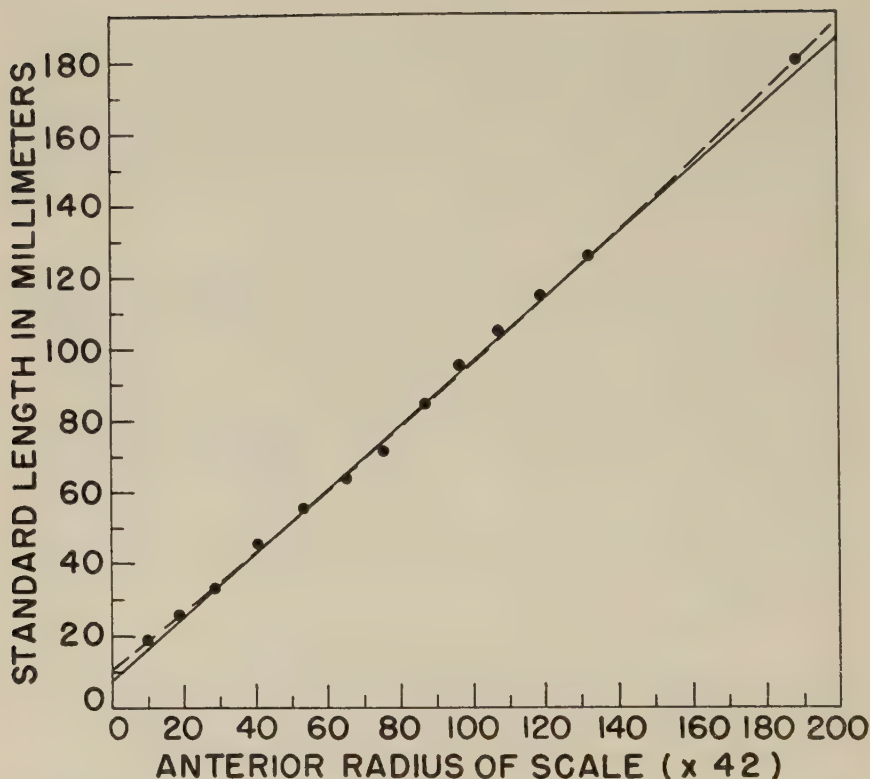


FIGURE 1.—Body-scale relationship of McFarland Pond bluegills. The dots are based on the average measurements in Table 3. Formulas for the straight and curvilinear lines are given in the text.

lengths represented by small numbers of fish. Slight discrepancies also appeared in the middle size groups where the size of the sample was considered adequate.

In an attempt to obtain a more satisfactory representation of the body-scale relationship, the data were fitted by the least squares method with a curvilinear regression line (Fig. 1) represented by the third-degree polynomial:

$$L = 11.42 + 0.79469 S + 0.00048 S^2 + 0.000000106 S^3.$$

The resulting flat curve does not differ greatly from the straight line, and it was difficult to conclude by visual observation the extent to which it described the relationship between the standard length and the scale radius better than the straight line. Hence, the sums of squares of deviations of the data from the regression lines were calculated and compared (Rider, 1939) to determine mathematically the "goodness of fit." The resultant

sums of squares of deviations were: linear regression line, 33.81; curvilinear regression line, 4.24. The pronounced difference between the two values indicated that the curvilinear regression line gave by far the better mathematical fit to the data.

Nomographs were prepared for the body-scale relationships as determined by the linear and curvilinear regression formulas (Carlander and Smith, 1944). Growth history was then computed for each individual in the 1945 and 1948 year classes from both formulas. Specimens in the 1945 year class were in age-group IV when collected and 77 percent of the 1948 year class fish were in age-group I. Groups I and II of the 1948 year class were combined for comparison of the growth calculation formulae because so little growth was achieved in the second year of life that there was considerable overlap in the length ranges of the two age groups. The earlier growth increments calculated by the two methods differed by an unimportant amount (Table 4). Greater differences were noted among the

TABLE 4.—*Difference in length at formation of earlier annuli of McFarland Pond bluegills when calculated on the basis of linear and curvilinear regression formulas*
[All lengths and deviations in millimeters]

Standard length	Number of specimens	Values computed from curvilinear regression				Deviation of linear from curvilinear regression values			
		1	2	3	4	1	2	3	4
1948 year class									
40- 49	48	40.8	....	....	....	-1.2	...	...	...
50- 59	275	42.0	52.0	....	....	-0.2	+0.3	...	...
60- 69	198	47.0	58.4	....	....	-0.2	+0.4	...	...
70- 79	47	51.2	67.2	....	....	-0.5	-0.4	...	...
80- 89	9	53.0	74.0	....	....	+0.2	-0.2	...	...
1945 year class									
170-179	3	55.5	90.0	123.0	166.2	+1.1	+3.3	+3.0	+1.4
180-189	2	48.9	76.5	104.2	156.0	+1.1	+3.0	+2.8	+1.5

larger fish. Though slightly less accurate, calculations based on linear regression appear to be satisfactory for describing the growth history of McFarland Pond bluegills.

DIFFERENCES IN GROWTH RATE

Growth histories (Table 5) were calculated on the basis of the linear body-scale formula given in the preceding section. Individuals of a year class were lumped together for this compilation regardless of age grouping because the calculated growth histories of different age groups within the same year class were found to be in reasonably good agreement. The differences in growth rate between male and female bluegills spawned in McFarland Pond were not consistent in the first year of life but males tended to grow the faster in later years (Table 6). Although the size of

the 1945 year class is considered inadequate, it is interesting to note that males of this year class exhibited greater growth annually until their fourth year when the females' average increment became nearly double that attained by the males.

First-year growth of fish actually improved from 1947 to 1949 although it did not match that attained by the 1945 year class which was spawned in a different environment (Tables 5 and 6). Rather marked decrease in growth increments occurred, however, in 1947 and 1948 year classes as

TABLE 5.—*Summary of the average calculated standard lengths and growth increments for each year of life of McFarland Pond bluegills collected in 1949 and 1950*

Year of life	Calendar year				
	1945	1946	1947	1948	1949
Calculated length (millimeters)					
4	..	..	...	164	...
3	..	..	127	...	82
2	..	88	...	67	60
1	54	..	37	45	45
Increment of length					
4	..	..	...	37	...
3	..	..	39	...	15
2	..	34	...	30	15
1	54	..	37	45	45
Number of fish caught in, 1949	5	..	278	251	...
1950	..	..	96	333	165

age increased. Indeed, the average increments achieved by fish in age-groups I and II in 1949 were so low as to suggest that growth was becoming stunted. An average increment as low as 15 millimeters has not been reported for the second year of life in any other growth study on bluegills, and in only a few stunted populations has the increment for the third year been as low. In addition, the average standard lengths at capture in 1950 of fish from age-groups I and II did not show the pronounced progressive increase in length with advancing season that would be expected of normally growing fish (Table 7). These fish appeared to have grown little from July 1949 to July 1950. Although the lengths at capture of O-group fish showed a more regular increase as the season progressed, the growth rates of other age groups in 1949 were, in general, much reduced.

Annual increments of length in age groups of the 1945 year class fish were greater than those of later year classes in corresponding years of life. The 1945 year class individuals, however, spent their first 2 years in another environment and were not introduced into McFarland Pond until the beginning of their third year of life.

It is difficult to understand why young of the year bluegills in McFarland Pond achieved a smaller average first-year increment in 1947 than

TABLE 6.—Summary of calculated average standard lengths and length increments for each year of life of male and female bluegills collected from McFarland Pond in 1949 and 1950
[Number of specimens in parenthesis]

Year class	Year of capture	Age group	Calculated length (millimeters) at end of year of life ¹							
			1		2		3		4	
			Male	Female	Male	Female	Male	Female	Male	Female
1949	1950	I	45 (36)	45 (82)	..	..	..	..	..	..
1948	1949	I	45 (93)	47 (100)	..	..	..	..	..	..
	1950	II	45 (141)	43 (173)	61 (141)	58 (173)	..	..	..	..
1947	1949	II	37 (146)	37 (131)	69 (146)	66 (131)	..	..	..	..
	1950	III	37 (47)	38 (49)	65 (47)	65 (49)	83 (47)	80 (49)	..	..
1945	1949	IV	57 (3)	50 (2)	93 (3)	80 (2)	141 (3)	107 (2)	168 (3)	158 (2)
Grand average			42 (466)	42 (537)	65 (337)	62 (355)	86 (50)	81 (51)	168 (3)	158 (2)

Annual increments (millimeters)										
1949	1950	I	45	45	..	..	..	..	..	..
1948	1949	I	45	47	..	..	..	..	..	..
	1950	II	45	43	16	15	..	..	..	..
1947	1949	II	37	37	32	29	..	..	..	..
	1950	III	37	38	28	27	18	15	..	..
1945	1949	IV	57	50	36	30	48	27	27	51
Average annual increment ²			42	42	25	21	20	16	27	51

¹ Specimens passed into the next higher age group on January 1

² Calculated by weighted averaging of annual increments of age groups concerned

TABLE 7.—Standard lengths of bluegills at times of capture in McFarland Pond
[Number of fish in parenthesis]

Year class	Year of capture	Age group	Average standard length (millimeters) at capture									
			Jan.-Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.-Dec.	
1949	1949	0	.. 47 (7)	.. 46 (89)	.. 47 (23)	33 (25) 52 (37)	37 (8) 51 (9)	.. ..	39 (13) ..	47 (7) ..	47 (10) ..	
	1948	I	..	..	48 (56)	54 (51)	57 (49)	61 (11)	59 (22)	60 (21)	60 (41)	
1947	1949	II	60 (61)	59 (114)	61 (81)	66 (59)	67 (18)	..	..	..	..	
	1950	II III	77 (7)	83 (46)	72 (19) 83 (16)	85 (77) 85 (14)	86 (37) 84 (13)	82 (69) ..	91 (50) ..	80 (10) ..	81 (17) ..	
1945	1949	IV	..	..	..	182 (4)	..	..	175 (1)	..	..	

in later years. Data are too limited for a complete evaluation of the abundance and availability of the food supply in the new pond that year but possibly even the 23 parent-stock bluegills had some difficulty in finding adequate food in the first post-introduction year. It is possible that the food required by bluegill fry and fingerlings was not as plentiful as in later years. In attempting to explain the less rapid growth of newly spawned fish during the first year of impoundment of Norris Reservoir, Eschmeyer and Jones (1941) attributed the greater initial growth of the fish spawned in later years in part to a possible increase in available food as the impoundment aged. Delayed spawning offers an alternative explanation for the slower initial growth of the 1947 year class in McFarland Pond. When the brood stock were released in the pond on May 23, 1947, they exhibited no evidence of being ready to spawn. The spawning was probably somewhat delayed and the growing season of the young of the year may consequently have been of less duration than usual.

It is even more difficult to explain satisfactorily the seeming lack of growth in 1949 and 1950 by the 1947 year class (age-groups II and III) as being other than stunting. The average size at capture in July 1950 was smaller than it was when the fish were a year younger (Table 7). Although part of this apparent discrepancy may be due to sampling errors, the evidence suggests strongly that the larger individuals of the 1947 year class disappeared before 1950, leaving only the slower growing specimens (this selective disappearance was not particularly reflected in the earlier growth history of age-group III—Table 6). It has been suggested frequently that faster growing individuals do not live as long as slower growing individuals in the same population, but it is not known whether the differential mortality occurs as early in life as these data might indicate.

There is another possible explanation for the decrease in the average standard length of the 1947 year class specimens collected during the period July 1949–July 1950. Some of the bluegills classed as members of the III group in 1950 might actually have been II-group fish in which false annuli were interpreted as true year-marks. Inclusion of a relatively small number of such younger fish might be expected to reduce the average size of the age group as indicated. Even if this proved to be correct, one would have expected to find that the largest age-group III fish taken in 1950 was larger than the largest age-group II individual examined in the previous year. Such, however, was not the case. In addition, a higher percentage of the age-group II fish was found to have achieved a length of 85 millimeters in 1949 than was true of the group III fish in 1950.

LENGTH OF GROWING SEASON

Increase in length evidently started at about the same time that the new annuli were formed in McFarland Pond fish. Young of the year bluegills made rapid growth to late June of 1949 and continued to grow thereafter at a much reduced rate, possibly until late September or early October (Table 7). Thus, young of the year spawned in mid- or late summer were probably able to accomplish at least a small amount of growth before

winter. Most of the growth of the I- and II-group bluegills in 1949 occurred in June; little or no growth took place in the yearlings after late July (Table 8) but some increase of length evidently occurred in the 2-year-olds until early September. In 1950, some individuals of age-groups I and II began new growth as early as the first week in April and maintained a slow rate of growth through at least the first week in July.

Beckman (1943) found that yearling bluegills in Pasinski Pond, Michigan, completed 85 percent of the expected growth for the season by July, but other workers as Bennett, Thompson, and Parr (1940) and Burress (see Footnote 4) reported substantial amounts of growth in yearling bluegills in Illinois and Missouri as late as September and October. Burress concluded from recoveries of tagged fish that time of cessation of growth was as variable as was the time of resumption of growth. It was evident that in McFarland Pond the greatest amount of growth usually occurred in late May or early and mid-June. Activities of McFarland Pond fish began to be restricted to shallower strata in mid-June because of stagnation and oxygen depletion in the greater depths (Sprugel, 1952).

FALSE ANNULI

Difficulties in the use of scales for age and growth determination in certain fish populations arise chiefly from the presence of supernumerary scale marks. Hile (1931), Ricker (1942), Bennett, Thompson, and Parr (1940), Bennett (1948), and Burress (see Footnote 4) discussed and suggested means of identifying false marks on bluegill scales. On many scales false annuli are easily recognized, but on some these extra marks are indistinguishable from true annuli on the basis of presently used criteria.

Unanimity of opinion is lacking in regard to the causes of supernumerary marks. From studies of the bluegills of Fork Lake, Illinois, Bennett (1948) agreed with other authors who believe that scale abnormalities are more common in fish with either rapid or extremely slow growth than in those of average growth. He also referred to some unpublished results of laboratory feeding experiments conducted by von Limbach in which false annuli were formed in bluegills which began feeding heavily after periods of refusing to take full quotas of food. Burress (see Footnote 4) found the largest number of supernumerary marks in fast-growing bluegill populations. He reported that these false annuli formed in June and July when water temperatures of the pond ranged between 80° and 90°F. at the surface and between 70° and 72°F. at the bottom. Others have attributed the production of extra scale marks to excessive water temperature, spawning activities, and turbidity.

Distinct regions of retarded and increased growth were found between the focus and first annulus on many bluegill scales from McFarland Pond. The nature of these markings varied considerably from fish to fish. Scales of some individuals did not possess a region of retarded growth in the first-year field other than that immediately preceding the annulus; in scales from other fish increases or decreases in the distance between circuli were gradual. On some scales, however, growth was so reduced at some time during the

TABLE 8.—Average growth in length¹ beyond time of formation of the last annulus in 1949 and 1950 by McFarland Pond bluegills
[Increments in millimeters]

Date of collection	Age - group I			Age - group II			Age - group III		
	Number of fish	Number with new annulus	Growth increment	Number of fish	Number with new annulus	Growth increment	Number of fish	Number with new annulus	Growth increment
1949									
May 1-2.....	56	21	0.7	19	13	1.7	..	..	..
June 3-13.....	32	31	8.3	54	54	13.3	..	..	..
June 21-28.....	19	19	13.8	23	23	21.4	..	..	..
July 1-12.....	9	9	12.2	21	21	20.6	..	..	..
July 20.....	40	40	12.8	15	15	16.5	..	..	..
Aug. 3-5.....	11	11	15.7	69	69	16.5	..	..	..
Aug. 3-5.....	18	18	14.0	44	44	23.4	..	..	..
Sept. 3-10.....	4	4	16.2	6	6	17.5	..	..	..
Sept. 24.....	21	21	13.6	10	10	15.9	..	..	..
Oct. 16.....	9	9	14.9	8	8	18.8	..	..	..
Nov. 14.....	32	32	15.6	9	9	13.1	..	..	..
Dec. 17-30.....	333	..	17.3	96	..	15.7	..	..	..
Feb. 4-July 7, 1950 ²									
1950 ³									
Feb. 4-10.....	..	..	..	13	1	0.1	..	..	..
Apr. 4-10.....	77	2	0.1	76	6	0.2	..	..	..
Apr. 17-24.....	12	1	0.2	38	6	0.5	..	..	..
May 1-12.....	11	1	0.4	34	13	0.9	..	..	..
May 15-31.....	12	3	0.7	47	35	1.9	13	1	0.8
June 5-7.....	17	17	7.5	33	30	5.3	7	3	1.8
June 19-28.....	20	20	9.9	26	26	8.0	7	7	10.7
July 7.....	9	9	10.2	18	18	8.3	13	13	8.4

¹ Computed from increments of scale beyond the last annulus² Each estimate based on members of the same year class captured after January 1, 1950, but does not include growth completed beyond the 1950 annulus; the increments are therefore estimates of the full-season growth in 1949³ New growth increments were computed for only those collections made in periods in which fish with a 1950 annulus were taken

first year that a false mark was formed when faster growth was resumed (Fig. 2). These accessory marks, often had the appearance of weakly defined first annuli, but their false character was proven by their occurrence on the scales from young of the year fish and by their presence on scales of members of the 1947 year class taken in 1949. If the first checks on scales of 1947 year class fish caught in 1949 had been considered to be true

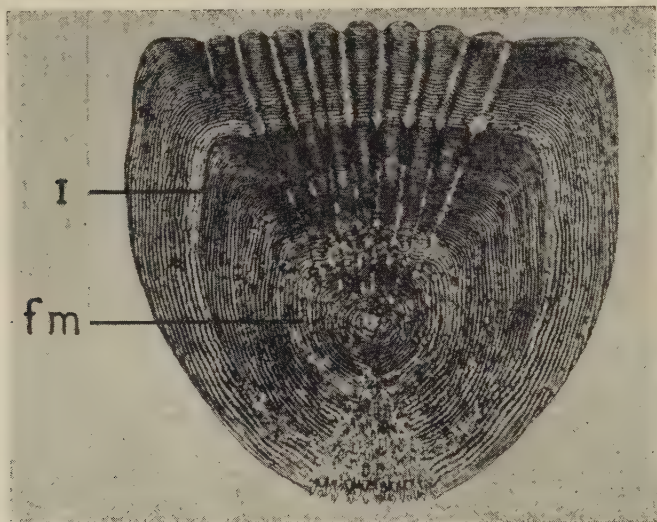


FIGURE 2.—Photomicrograph of scale from a male bluegill collected February 10, 1950, showing a false mark (fm).

annuli, their estimated ages would have been 3 years. No bluegills of age-group III could have been present in McFarland Pond at that time. Young of the year individuals taken in 1949 apparently laid down the supernumerary mark at an average calculated length of 21 or 22 millimeters in middle or late June. This length corresponds reasonably well with the lengths at which early false marks were formed on young in 1947 and 1948 (Table 9).

Apparently conditions are more conducive to the formation of accessory checks in some years than in others. The percentage of scales with false annuli in the first-year field was only 10.6 in the 1947 year class as compared with 93.8 and 89.4 in the 1948 and 1949 year class, respectively (Table 9).

The causes of temporarily retarded scale growth and of the frequently accompanying false check in the first year of life are not definitely known. Decrease in the food supply or unsatisfactory chemical and/or physical conditions of the water may have contributed to the temporarily decreased growth rate. A change from one type of food to another by the young fish offers another possible explanation. Fry first consume smaller plankton

forms and then change to larger items of food. The change from very slow to rapid growth on the scales might be a reflection of the change in feeding habits. If this explanation is true, the low incidence of false marks in the first-year growth field in 1947 and the comparatively slow first-year growth in that season (Table 5) may indicate that the intermediate-sized food organisms were relatively scarce in the new lake.

Production of false annuli in fish older than 1 year occurred most frequently in members of the 1947 year class. This does not imply, however, that the tendency toward formation of accessory checks was necessarily an attribute of the year class. Some 10 percent of II-group bluegills taken

TABLE 9.—Incidence of first-year accessory marks on scales of McFarland Pond bluegills

Year class	Number of fish	Fish showing first-year accessory marks		
		Number	Percentage of total	Average calculated length (millimeters) when marks formed
1949	228	204	89.4	29
1948	584	548	93.8	21
1947	374	40	10.6	20
1945	5	4	80.0	26

subsequent to June 1 in 1949 and of III-group fish collected in 1950 exhibited a false mark following the first or second annulus. The supernumerary marks developed in the II-group fish in early or mid-June immediately following a period of very rapid growth in which these particular fish achieved an increment of 20 millimeters or more in approximately 3 weeks. By the time the II-group specimens with false marks were collected in 1949 they had grown nearly twice as much as that calculated to be average for the age group in that year, although their annual increments in previous years had not been exceptionally large. Although the fish with false annuli had all grown rapidly, other fast-growing fish in age-group II, did not form false marks in 1949.

Only 1 percent of 549 bluegills from the 1948 year class exhibited extra marks after the first year of life. Although these marks too were formed after a period of relatively fast growth in early June of 1949, a few other I-group fish from this stunting population showed relatively rapid growth without producing false marks. No supernumerary marks on McFarland Pond fish could be attributed directly to continuously unsatisfactory growth conditions.

All II-group individuals exhibiting new false checks in 1949 were males. Four of the I-group specimens showing these marks in the same year were females. In most fish the condition of the sex organs was such that the production of false annuli could have been associated with spawning activities.

A rather extensive study of the physical and chemical conditions in McFarland Pond during the period in which false scale marks were formed

failed to show that these conditions caused the formation of accessory marks.

No simple, dependable criteria were found for the recognition of false annuli; hence, no definite rules of procedure can be offered. Some general observations relevant to recognition of false marks on bluegills scales follow:

a. A scale mark preceded by a zone of relatively widely separated circuli and followed by closely spaced circuli is usually a false annulus.

b. An examination of adjacent scales from the same fish frequently reveals the character of a mark that lacks continuity or clarity of definition. False marks may be missing or indistinct on the adjacent scales but true annuli usually are clearly defined on all scales.

c. Particularly dark bands appearing on a scale should be treated with suspicion.

d. Lack of extensive anastomosis of circuli with the mark and limited extension of the mark across the postero-lateral field of the scale frequently characterize accessory checks but do not necessarily identify them.

e. If the position of a mark with respect to adjacent annuli differs greatly from that on scales from other fish in the same size-group within a year class it may be suspected as possibly false.

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SEASONAL FLUCTUATIONS IN THE FEEDING OF BROOK TROUT IN THE PIGEON RIVER, MICHIGAN¹

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ABSTRACT

Stomach contents were analyzed for 420 specimens of wild brook trout (*Salvelinus fontinalis*) from the Pigeon River, Otsego County, Michigan. All fish were caught by anglers and checked by trained personnel from April 26 to September 14, 1952. Data on coefficient of condition and volume of stomach contents were averaged by 2-week periods. Both condition and volume of stomach contents were highest in May and June and decreased thereafter during the angling season. The data suggested a close relationship among periodicity of growth, condition, and mean volume of stomach contents.

The most common organisms eaten by brook trout during the period of most rapid growth and best condition were mayflies, caddisflies, and crayfish. Stream temperatures were 55° to 66° F. when the trout were in the best condition and had the greatest volume of food in their stomachs. Both laboratory and field studies have shown this temperature range to be optimum for feeding and activity of brook trout. It is suggested therefore, that growth rate depends upon optimum temperatures and on the abundance of food during the period of optimum temperatures.

INTRODUCTION

Knowledge of the factors that determine rate of growth are of primary importance in the management of trout. At the Pigeon River Trout Research Area, Otsego County, Michigan, the rate and periodicity of growth of brook trout were investigated by Cooper (1953a and 1953b) who showed that most of the annual growth was made during May and June. After this period, the growth rate decreased until mid-winter when the fish grew little or not at all. During the period of most rapid growth, the coefficient of condition was also at its maximum. The coefficient decreased gradually thereafter and reached a minimum in late winter in a manner similar to that of growth rate. Cooper suggested, therefore, that a correlation existed between rate of growth and condition. The possibility that food supply was a salient factor in determining the condition and rate of growth was also indicated. Other workers have likewise noted a close relationship between condition and rate of growth in fishes (Brown, 1946; Stroud, 1949; Hansen, 1951).

The purposes of the present study on brook trout (*Salvelinus fontinalis*)

¹ Contribution from the Institute for Fisheries Research, Michigan Department of Conservation.

were to investigate the seasonal variation in kind and volume of stomach contents and coefficient of condition. The relationships of these factors to periodicity of growth and stream temperatures were noted.

METHODS

This investigation was based on examination of 420 wild brook trout that were caught by anglers from April 26 to September 14, 1952, on the Pigeon River Trout Research Area. A permit system of angling was used whereby all angler-caught fish were examined by trained personnel. Lengths, weights, scale samples, and stomachs were collected from more than 90 percent of the fish. The coefficient of condition, R (Cooper and Benson, 1951) was computed for each fish.² Each stomach was first preserved in a 10-percent solution of formalin and later transferred to 70-percent alcohol. Later, the contents of each stomach were separated into broad taxonomic groups and measured by volumetric displacement. The data were grouped by 2-week periods except for the last 16 days of the season. Continuous records of stream temperature were obtained by a recording thermometer located approximately in the center of the experimental area.

In a previous study, Cooper (1953b) demonstrated that the use of angler-caught fish caused much bias in the analysis of periodicity of growth. He showed that, throughout the season, anglers remove the most rapidly growing fish, and that it was consequently impossible to demonstrate clearly the periodicity of growth in this stream with angler-caught fish. Periodicity of growth was not analyzed in this study.

SEASONAL TREND IN VOLUME OF STOMACH CONTENTS

Within each 2-week period, the volume of the contents of the individual trout stomachs showed great variation. This variation was due to several factors: (1) specimens were caught at different times of the day, (2) type of food eaten varied greatly in volume, and (3) size of the individual fish varied. It was not possible to determine accurately the time of day when the individual fish were caught. Single food organisms such as crayfish or small fish gave larger volumes than did a large number (100-200) of minute animals such as mayfly nymphs or caddis larvae. Although large brook trout (9 inches long or larger) made up only 14 percent of the sample they usually¹ had, as expected, a greater volume of food than did the smaller fish (Table 1). In this study, the mean volume for each 2-week period was considered to be the significant figure. Minor variations in food volume among individual fish were thereby discounted. For all sizes of fish, the volume of the stomach contents increased in May and June but later decreased up to September 14 (Table 2). The stomach contents were the greatest, however, during the first 2 weeks of the angling season.

² $R = \frac{W \times 100}{L^3}$ where W = weight in grams and L = total length in inches.

TABLE 1.—Mean total volume (cubic centimeters) of stomach contents according to date of collection, and size of brook trout

Period of collection	Total length (inches)					
	6.8-7.0		8.0-8.9		9.0-12.9	
	Number of fish	Mean volume	Number of fish	Mean volume	Number of fish	Mean volume
April 26-May 9.....	32	1.008	9	1.839	5	3.120
May 10-May 23.....	20	1.160	9	0.917	3	0.626
May 24-June 6.....	32	0.657	13	1.355	9	1.833
June 7-June 20.....	16	0.745	5	0.185	5	0.400
June 21-July 4.....	58	0.512	2	0.125	2	0.625
July 5-July 18.....	28	0.407	6	0.338	3	1.660
July 19-Aug. 1.....	15	0.260	3	0.333	1	0.025
Aug. 2-Aug. 15.....	46	0.304	8	0.404	8	0.200
Aug. 16-Aug. 29.....	17	0.225	..	.....	8	0.125
Aug. 30-Sept. 14.....	33	0.215	10	0.290	14	0.418
Total.....	297	.....	65	.....	58	.....

SEASONAL TRENDS IN COMPOSITION OF FOOD

Mayflies (principally *Ephemerella* and *Rithrogena*), crayfish, and caddisflies (largely *Glossosoma*) were present in the greatest volume during May and June (Table 2). Mayflies and caddisflies occurred in a large percentage of the stomachs and thus possibly benefited more fish than did crayfish (Table 3). Diptera occupied a small part of the volume of stomach contents, although their volume increased in August when the larger terrestrial adults (e.g., the family Asilidae) became available. Dragonflies made up a small part of the volume during most of the season, but a large part during the last few weeks of June and early July when both nymphs and adults were consumed in large numbers. Various fishes (principally *Cottus* spp. and *Rhinichthys a. atratulus*) were present in considerable volume during the middle of June but occurred in few stomachs. Grasshoppers appeared first during the latter part of June and constituted a significant part of the stomach contents from that time until the middle of July. The importance of earthworms as a natural food cannot be fully evaluated from angler-caught fish because several of those found were believed to be the bait that caught the fish. Other forms such as Mollusca, Megaloptera, Plecoptera, Hemiptera, Hymenoptera, Lepidoptera, and Arachnida were never found in large volumes at any period. Since unidentifiable remains made up from 17.9 percent to 44.8 percent of the volume of the stomach contents, no definite conclusions could be made on the relative values of taxonomic groups.

RELATIONSHIPS OF FEEDING TO COEFFICIENT OF CONDITION,
TEMPERATURE AND GROWTH

Coefficient of condition of the 420 brook trout used in the food study was greatest during May and June and declined generally thereafter (Figure 1). It was low, however, during the first 2 weeks of the angling

TABLE 2.—Mean volume (cubic centimeters) and percentage composition of stomach contents of 420 brook trout by 2-week periods

Period of collection	Number of fish	Food item										Mean total volume per fish	Standard error of mean volume
		Annelida	Crayfish	Orthoptera	Ephemeroptera	Odonata	Megaloptera	Trichoptera	Diptera	Fish	Miscellaneous ¹	Unidentified remains	
April 26-May 9	46	0.086 6.1	0.217 15.5	.....	0.212 15.1	0.027 1.9	0.055 3.9	0.170 12.1	0.046 3.3	0.033 2.4	0.131 9.4	0.423 30.2	0.180
Volume	..												
Percentage	..												
May 10-May 23	32	0.136 13.1	0.064 6.1	.....	0.247 23.7	0.029 2.8	0.016 1.5	0.031 3.0	0.016 1.5	.....	0.036 3.5	0.466 44.8	0.166
Volume	..												
Percentage	..												
May 24-June 6	54	0.069 6.8	0.406 39.8	.....	0.073 7.1	0.022 2.2	0.006 0.6	0.056 5.5	0.017 1.7	.....	0.073 7.1	0.299 29.2	0.169
Volume	..												
Percentage	..												
June 7-June 20	26	.....	0.085 14.9	.....	0.053 9.3	0.004 0.7	0.038 6.7	0.009 1.6	0.010 1.7	0.071 12.4	0.089 15.6	0.212 37.1	0.116
Volume	..												
Percentage	..												
June 21-July 4	62	0.033 6.8	0.024 4.9	0.076 15.7	0.010 2.1	0.163 33.6	0.005 1.0	0.002 0.4	0.014 2.9	0.024 4.9	0.030 6.2	0.104 21.4	0.081
Volume	..												
Percentage	..												
July 5-July 18	37	.....	0.030 8.0	0.062 16.5	0.003 0.8	0.081 21.5	0.005 1.3	0.000 0.0	0.015 4.0	0.014 3.7	0.017 4.5	0.149 39.7	0.054
Volume	..												
Percentage	..												
July 19-Aug. 1	19	0.003 1.1	0.001 0.4	0.037 14.3	0.010 3.9	0.029 11.2	.....	0.007 2.7	0.046 17.8	0.016 6.2	0.044 17.0	0.066 25.4	0.048
Volume	..												
Percentage	..												
Aug. 2-Aug. 15	62	0.035 11.5	0.066 21.7	0.007 2.3	0.009 3.0	0.020 6.6	.....	0.006 2.0	0.066 21.7	.....	0.027 8.9	0.068 22.3	0.054
Volume	..												
Percentage	..												
Aug. 16-Aug. 29	25	0.008 4.1	0.032 16.5	0.010 5.2	0.008 4.1	0.044 22.8	.....	0.021 10.9	0.027 14.0	.....	.....	0.043 22.3	0.046
Volume	..												
Percentage	..												
Aug. 30-Sept. 14	57	0.005 1.8	0.109 39.2	0.024 8.6	0.003 1.1	0.018 6.5	0.001 0.4	0.006 2.2	0.014 5.0	.....	0.048 17.3	0.050 17.9	0.071
Volume	..												
Percentage	..												

¹ Includes Mollusca, Plecoptera, Hemiptera, Hymenoptera, Lepidoptera, and Arachnida² Less than 0.0005³ Less than 0.05

TABLE 3.—Frequency of occurrence of different types of organisms in stomachs of brook trout, and percentage of empty stomachs

Period of collection	Number of stomachs	Percentage of empty stomachs	Percentage containing food item								
			Annelida	Crayfish	Orthoptera	Ephemeroptera	Odonata	Megaloptera	Trichoptera	Diptera	Fish
April 26-May 9.....	46	....	23.9	15.2	....	89.1	10.5	17.3	78.2	52.5	10.8
May 10-May 23.....	32	....	21.8	15.6	....	75.0	6.2	3.1	18.9	25.0	....
May 24-June 6.....	54	....	11.1	35.1	....	50.0	5.5	1.8	42.5	14.8	....
June 7-June 20.....	26	....	....	15.3	....	46.1	3.8	7.6	26.3	23.0	7.6
June 21-July 4.....	62	9.2	3.2	3.2	19.3	24.1	24.1	4.8	11.2	24.1	1.6
July 5-July 18.....	37	21.6	....	10.8	21.6	21.6	24.3	2.7	10.8	16.2	5.4
July 19-Aug. 1.....	19	10.5	5.2	5.2	10.5	31.5	15.7	....	31.5	42.1	5.2
Aug. 2-Aug. 15.....	62	3.2	8.0	14.5	6.4	33.8	8.0	....	19.3	48.3	....
Aug. 16-Aug. 29.....	25	24.0	4.0	8.0	4.0	24.0	12.0	....	28.0	20.0	....
Aug. 30-Sept. 14.....	57	1.7	3.5	29.0	5.2	12.2	3.5	1.7	17.5	24.5	....

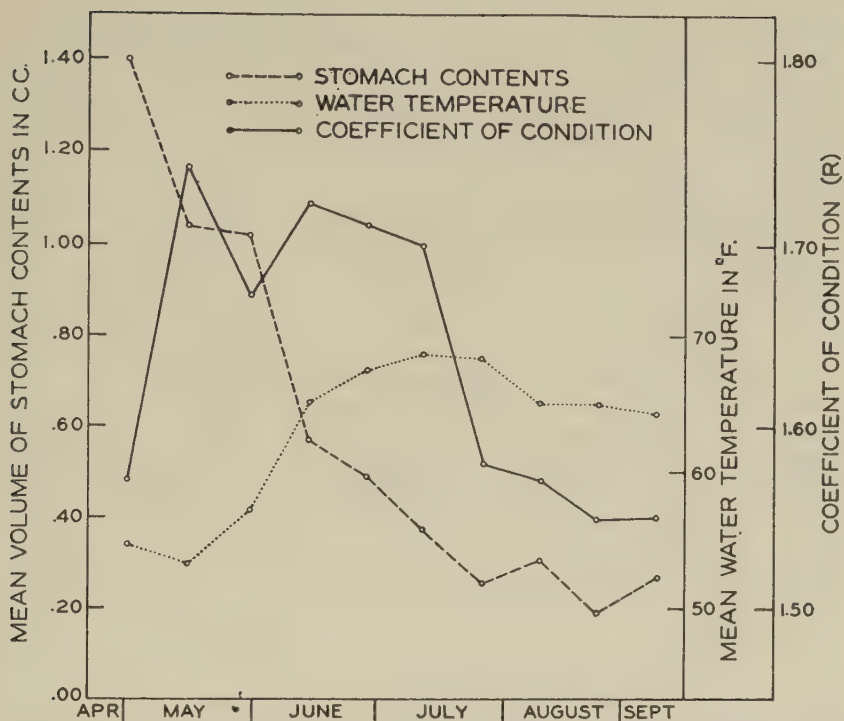


FIGURE 1.—Mean volume (cubic centimeters) of stomach content of 420 brook trout (broken line), mean coefficient of condition of same brook trout (solid line), and mean stream temperature (dotted line) in the Pigeon River, by 2-week periods.

season. Similar findings on Pigeon River brook trout have already been reported (Cooper and Benson, 1951; Cooper, 1953a). Mean stream temperatures by 2-week periods were lowest (55° to 66° F.) during the first month of the angling season and reached a maximum (68° F.) in July.

The bi-weekly averages suggest a close relationship between volume of food in the stomachs of legal-sized (7-inch or longer) brook trout and the coefficient of condition. Both were highest during May and June and decreased thereafter. Since an earlier study (Cooper, 1953a) suggested that growth in length occurred mostly when Pigeon River brook trout were in best condition, *i.e.*, during May and June, we may assume that contents of trout stomachs in these months were important as growth foods. The most common food organisms in brook trout stomachs in May and June were mayflies, caddisflies, and crayfish. Needham (1930) stated that mayflies and caddisflies were the principal foods of brook trout during May and June in New York state. Frost (1945) found that the mayfly (*Ephemera*) was common in the stomachs of rapidly growing brown trout (*Salmo trutta*) on the River Liffey, Ireland, even though it formed

a small part of the "moss" fauna. She concluded that quality of food organisms could explain variation in growth more easily than could quantity.

Several other workers have considered temperature as an important factor limiting growth. Purkett (1951) found that the growth rate of rainbow trout (*Salmo gairdneri*), cutthroat trout (*S. clarki*), and hybrids (*gairdneri* $\times$ *clarki*) in a Montana stream varied mainly with the temperature and not with coefficient of condition; however, the fish for his study were collected at various times in the angling season, and seasonal change in condition, if it did occur, was not considered. Hazzard (1933) also believed temperature to be a limiting factor on growth of rainbow trout in high mountain lakes and streams. Cooper (1953a) held that slow growth of brook trout in Hunt Creek could not be explained as the result of low temperatures; temperatures in Hunt Creek were near the optimum for growth throughout the major part of both summer and fall.

Fry (1951) reviewed both laboratory and field studies on the brook trout and suggested that the best temperature range for activity and growth was 55° to 66° F. In the Pigeon River (Fig. 1) the greatest volume of food in the stomachs was present when the water temperatures were within the range cited by Fry. Furthermore, the condition and growth rate were greatest during this time. The growth rate of brook trout in the Pigeon River is dependent on temperature conditions and on the amount (and possibly kind) of food available when the temperatures are in the optimum range.

ACKNOWLEDGMENTS

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MICROSPORIDIAN PARASITE, *GLUGEA HERTWIGI*, IN
AMERICAN SMELT FROM THE GREAT BAY REGION,
NEW HAMPSHIRE¹

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ABSTRACT

Examination of 1,323 American smelt, *Osmerus mordax* (Mitchill), from the Great Bay region of New Hampshire during the period from October 1951, through April 1952 showed that 308 (23.3 percent) were infected with *Glugea hertwigi*. The serious pathological manifestations of the disease suggested that it is an important contributing factor to the recent decline in the smelt population of the area. Although the mode of transmission of the parasite from smelt to smelt is not known, it seems probable that it enters with the food—perhaps after prior mechanical concentration of the spores by one or more of the organisms utilized by the smelt for food. Additional study is needed on the problem of transmission.

INTRODUCTION

For many years the American smelt has been the principal economic product of the Great Bay region of New Hampshire. Warfel, Frost, and Jones (1942) stated, "The most important fish taken at the present time in the waters of the New Hampshire coast is the common smelt [it] is an item of considerable importance to a few fishermen who annually invest in the necessary gear for taking it in paying quantities and to several hundred sports fishermen who fish for it through the ice." Other investigators (Jackson, 1944, and Krochmal²) also regarded the smelt as the most valuable product of the Bay area.

In recent years, however, Professor C. F. Jackson (personal communication, 1951) and his students at the University of New Hampshire have noted a marked decrease in the smelt population of the bay region. They believe the major reason for the decline is a decrease in the number of suitable spawning beds due to the accumulation of silt and contamination of the water by industrial and human wastes. The results of the present study indicate that parasitism also may be an important contributing factor.

Investigation of a recent "die-off" among the smelt population of Loon Pond, Gilmanton, New Hampshire (Haley, 1952) showed that the

¹ Contribution from the Zoology Department, University of New Hampshire, Durham, New Hampshire.

² Krochmal, Stanley B. 1949. The ecology of the smelt *Osmerus mordax* (Mitchill) in Great Bay, New Hampshire. 85 pp. [Master's thesis; University of New Hampshire].

fish were heavily infected with a microsporidian parasite, *Glugea hertwigi* (Weisenberg 1911, 1913). Since this parasite was known also to occur in smelt which spent part of their life in salt water (Schrader, 1921; Haley, 1952) this study was undertaken to check its incidence and distribution in smelt from the bay area.

Great Bay is a large tidal flat. The northern portion joins a smaller body of water, Little Bay. According to Krochmal (see footnote 2) the total area of both bays is about 5,540 acres. Eight tidal rivers comprise the drainage system of the "Bay" which is approximately 700 square miles. The Piscataqua River, which is formed by the confluence of the Salmon Falls and Cocheco rivers, marks the boundary between Maine and New Hampshire, and flows into the Atlantic Ocean at Portsmouth, New Hampshire. Other rivers in the system include the Bellamy, Oyster, Lamprey, Exeter, and Winnicut. From the head of the tide water on the Salmon Falls River to the same point on the Exeter River is a distance of about 25 miles by channel.

METHODS

According to Goodrum³ the smelt enter the Bay in late fall and move up and down the rivers with the tides during the winter. The spawning runs begin in late March or early April and continue for 3 or 4 weeks, after which the fish return to the ocean.

From October 11, 1951, through April 20, 1952, a total of 1,323 smelt were collected from the bay and three of its tidal rivers—the Oyster, Lamprey, and Exeter. The fish were taken by seine in the fall and by hook and line through the ice in the winter. During the spring spawning runs considerable numbers were purchased from various commercial fishermen. The smelt were autopsied and the viscera, particularly the intestines, were examined for *G. hertwigi*. It was relatively easy to detect the parasite's presence since it produces marked hypertrophy of infected host cells with the resultant formation of distinctive white cysts. The milky fluid from several cysts was removed periodically and examined under the microscope for the parasites. The single polar filament was demonstrated by applying direct pressure on the cover glass of a fresh saline preparation as outlined by Kudo (1920). All measurements were made on fresh spores in saline preparations with the aid of a camera lucida. Finally, a few histological sections were made of normal and infected organs.

PATHOLOGICAL FINDINGS

Of the 1,323 smelt examined, 308 or 23.3 percent were infected with *G. hertwigi*. All degrees of infection were seen from one or two intestinal cysts to a severe invasion in which the intestine was covered with cysts and other organs such as the pyloric caeca, liver, gonads, and swimbladder

³ Goodrum, C. A. 1941. The distribution of fishes of Great Bay. 71 pp. [Master's thesis; University of New Hampshire].

were parasitized. No cysts were seen in the kidneys, spleen, or heart. The intestine was always the primary site of the disease and only in heavy infections were cysts found elsewhere. With the exception of a single cyst found in the esophagus and a few cysts noted in the stomach, the parasite was limited to the intestinal portion of the alimentary tract. The distribution of cysts along the intestine was variable. In some fish, the majority were located in the anterior third or the posterior third of the intestine, but in other smelt the cysts either were scattered irregularly or were grouped in different-sized clusters at intervals along the intestine. (Fig. 1) An extreme condition observed on several occasions was the protrusion of a few large cysts through the anus of the fish.

The shape of the cysts was somewhat variable and the size ranged from about 0.1 to 4.0 millimeters. Although the majority of cysts in a given fish had about the same size, some marked variation was noticeable. Variation in the average size of cysts was considerable from fish to fish. The fresh, elongated, pyriform spores measured 3.5 to 4.8 microns long by 2.0 to 2.6 microns wide. (Fig. 2)

Histological sections of the intestine showed degrees of destruction depending upon the intensity and duration of infection. In severe cases the masses of cysts were surrounded by small amounts of loose connective tissue, and little evidence of the normal intestinal tissue components could be found. The extensive mechanical damage caused by the parasite probably has a profound effect upon the normal secretory and absorptive functions of the intestine and thus on the general physiology of the host. The effect of cysts in the liver, gonads, and swimbladder was not ascertained, but they undoubtedly cause some impairment of the metabolism of the smelt.

Infected fish were obtained from four localities in the bay region (Table 1). A few fish were taken also from Seavey's Creek near Portsmouth, New Hampshire. The incidence of parasitism in smelt taken from the three rivers was somewhat higher than in the smelt collected from the bay. However, the majority of smelt from the bay were taken in January and February, whereas most of the fish examined from the rivers were collected in April. Whether this difference in incidence is related to time of the year or to other factors is not known. Diseased smelt were found in every month from October through April, with the exception of December and March when no collections were made. Since more than two-thirds of the fish were taken in April, additional studies are needed before a valid conclusion can be reached regarding seasonal variation in incidence.

Skerry⁴ found that the infection was nearly as prevalent in males as in females and occurred in all age groups from 1 through 5 years. Most of the fish were either 2 or 3 years old; consequently, the data on the other age groups were too fragmentary to be of significance. Skerry also noted some differences between the average total lengths of normal and infected fish.

⁴ Skerry, John B. 1952. A preliminary survey of the occurrence of *Glugea hertwigi*, Weissenberg, in the smelt, *Osmerus mordax* (Mitchill) of the Great Bay area, New Hampshire. 46 pp. [Master's thesis; University of New Hampshire.]



FIGURE 1

Top panel: Uninfected smelt.

Second panel: Smelt with a severe generalized infection of the intestine.

Third panel: Note the marked difference in cyst size here as compared with the smelt in the second panel. Note the heavily parasitized pyloric caeca.

Fourth panel: Smelt showing cysts concentrated in the anterior third of the intestine. Note the hepatic cysts.

Fifth panel: Smelt with cysts concentrated in the posterior third of the intestine. The cysts protruded through the anus of the fish before dissection.

Sixth panel: A heavy infection in the ovaries of a "ripe" female.

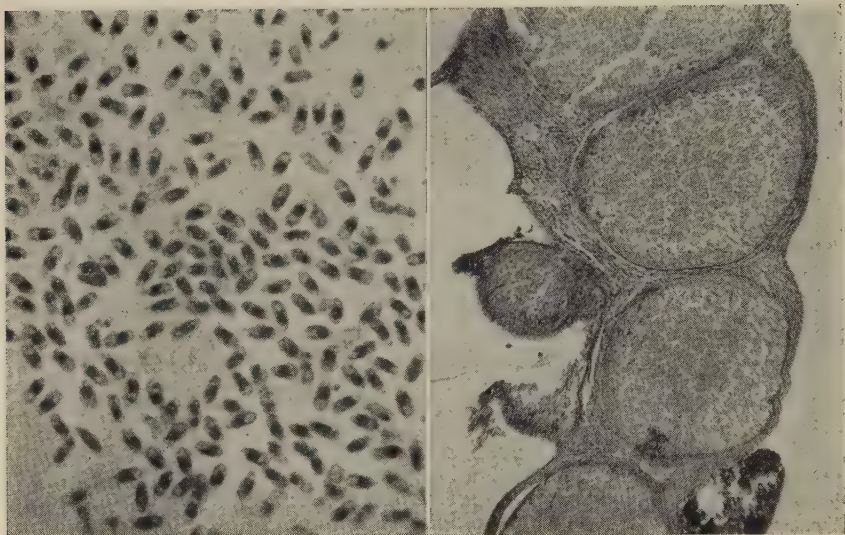


FIGURE 2.—Left: Spores stained with iron-hematoxylin and mounted in Fisher Permunt. Right: Cross section of an infected intestine showing the extensive damage caused by the formation of *Glugea* cysts.

SIGNIFICANCE OF THE INFECTION

If the present survey constitutes a representative sampling, nearly one-quarter of the smelt population of the Great Bay area was serving as hosts for *G. hertwigi* during the 1952 spawning season. This high rate of infection should be considered in attempts to explain the decline in the smelt population in the region. In the Oyster River where smelt runs have been exceedingly small for several years the incidence of infection was much higher than in the other localities surveyed. Interpretation of these data is largely speculative since only 84 Oyster River smelt were examined.

The incidence may be high and the degree of infection heavy among very young fish. Jackson (unpublished data) informed the writer that he noted numerous small, white intestinal cysts in about 48 percent of 500 3-month-old smelt which he seined from Great Bay in 1944. Bullock (personal communication, 1952) reported finding about one-third of large numbers of yearling smelt infected with *Glugea* cysts which could be seen in the fish without dissection.

The problem of how the parasite is transmitted from smelt to smelt as yet is unsolved. The release of spores into the water might occur in a variety of ways. When an infected fish dies spores undoubtedly are released from the cysts through degeneration of the body tissues as well as by the action of scavengers. It is also possible that when diseased smelt are eaten by their natural enemies the parasites pass through the predators' alimentary tracts unharmed and escape into the water with the feces.

Perhaps some spores reach the aquatic environment from cysts which have ruptured *in situ*, although no evidence of such ruptured cysts was detected. In view of the dilution factor involved in a volume of water as great as that of the bay area, a high incidence and heavy degree of infection would be difficult to explain even if one assumed a wide dissemination of spores by the above mechanisms. Infection may occur from direct ingestion of the spores but this possibility is minimized because marine fish take little or no water into their digestive tracts. It seems likely that the parasite must gain entry with the food. Perhaps the spores are concen-

TABLE 1.—*The incidence of infection of smelt by Glugea in five localities*

Locality	Number of smelt examined	Number of smelt infected	Percentage infected
Great Bay.....	374	55	14.7
Oyster River.....	84	44	52.4
Lamprey River.....	340	93	27.4
Exeter River.....	518	113	21.8
Seavey's Creek.....	7	3	42.9
Totals.....	1,323	308	23.3

trated in a mechanical fashion by one or more of the organisms utilized by the smelt for food. Such a concentration mechanism not only would help to explain a high incidence but also a heavy degree of infection.

A heavy parasitemia could be explained on the basis of repeated auto-infection. Kudo (1946) states that the spores of some species of Microsporidia seem capable of germinating in the same host, thereby increasing the number of infected cells. Quantitative tests are needed to determine whether or not this mechanism plays a role in the present problem.

Kudo (1924) pointed out that germinative infection definitely has been established for at least one microsporidian (*Nosema bombycis*) and has been suggested for several others. During the present study, cysts frequently were seen embedded in the egg mass of "ripe" female smelt (Fig. 1, Panel 6) and occasionally in the testes of the male, but this finding cannot be evaluated at the present time.

According to Breder (1948) the geographic range of the American smelt extends from the Gulf of St. Lawrence southward to Virginia. Smelt infected with *G. hertwigi* have been found at various localities extending from the coastal waters of northern Maine probably to Woods Hole, Massachusetts. Schrader (1921) reported a 1.5-percent incidence in smelt collected near Dennysville in northern Maine, and a 16-percent incidence in this species taken at Casco Bay farther south in the same state. Mavor (1915) apparently observed the parasite frequently in smelt from Woods Hole, Massachusetts, but he did not identify the parasite correctly. Limited examinations for sporozoan parasites have been made on smelt collected in the St. Andrews region of New Brunswick by Mavor (1915) and Ellis (1930) but no Microsporidia were found.

Diseased smelt are known to have been present in the Great Bay area at least since 1942. An examination showed infections with *G. hertwigi*

including involvement of the liver and ovaries in 6 of 53 formalin-preserved specimens provided by Professor Jackson. The fish were part of a sample taken by Warfel, Frost, and Jones (1942) from Great Bay.

ACKNOWLEDGMENTS

The writer wishes to thank Professor C. F. Jackson of the University of New Hampshire Zoology Department for his interest and valuable assistance throughout the study. Thanks are also extended to Robert Normandin, Henry Tomashevski, and Conservation Officer David Dupis for aid in the collection of the smelt. Special appreciation goes to John Skerry for his help in collecting as well as examining many of the fish. All photographs were made by John Anderson, graduate student in the Zoology Department, University of New Hampshire.

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VALIDITY OF AGE DETERMINATIONS FROM SCALES OF BROWN TROUT, RAINBOW TROUT, AND BROOK TROUT¹

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ABSTRACT

A total of 1,055 scale samples from tagged, recaptured brown trout, rainbow trout, and brook trout and 129 scale samples from planted, marked rainbow trout were taken from Prickley Pear Creek, Montana, between June 1949 and October 1951. In addition, scale samples were obtained from 69 rainbow trout planted as fry in Savage Lake, Montana, and from 42 known-age rainbow trout of the brood stock at the U. S. Fish and Wildlife Service Fish Hatchery, Ennis, Montana. Studies of these scales substantiated the general validity of the scale method of aging wild trout and trout planted as fry or young-of-the-year fingerlings.

Recaptured brown trout whose growth rate and annulus formation between growing seasons could be determined totaled 233; of these, 46 failed to form the expected annuli. Of 70 recaptured rainbow trout, 8 failed to form annuli, and of 3 brook trout, 1 failed to form an annulus. Most fish that failed to form annuli were more than 3 years old and had made little or no increase in body length.

Scales from rainbow trout brood stock of known age had "annuli" in varying numbers and positions on fish of the same age. These check marks did not conform to the known age of the trout and were probably caused by hatchery feeding practices and by handling during spawning operations.

Annuli beyond the third were, in general, in close proximity to one another and were difficult to detect. In some older fish, erosion or resorption obliterated scale characters.

INTRODUCTION

Although numerous investigations have been made on the age and growth of fishes in both Europe and America, few critical studies of the scale method have appeared, particularly in America. Van Oosten (1941) recognized the lack of such studies and stated that in over 150 papers, only some half dozen gave a critical evaluation of the scale method.

Studies on age and growth of trout in this country include those of Applegate (1947) who collected scales from known-age lake trout, *Salvelinus n. namaycush*, and Cooper (1951) who used tagged wild brook trout, *Salvelinus fontinalis*, to substantiate the scale method for fish more than 3 years old. Among related species Van Oosten (1923) described the scales from known-age whitefish, *Coregonus clupeaformis*, and Brown (1943) made a study of known-age grayling, *Thymallus signifer*.

¹ Contribution from the Montana Fish and Game Department and Montana State College Agricultural Experiment Station. Project No. MS 844, Paper No. 292, Journal Series.

This investigation concerns the characters of scales taken from known-age brown trout, *Salmo trutta*, rainbow trout, *Salmo gairdneri*, and brook trout. The objectives were: to provide a check on the scale method of aging wild trout; to determine possible effects of shocking, handling, and tagging of trout on scale characters; to determine whether hatchery-reared trout planted at different seasons differed as to scale characters; and to study the scale characters of hatchery brook stock held at nearly constant temperatures.

"Known-age" fish, in this report, include both wild and hatchery trout. Since the actual hatching dates of the wild trout were not known, the term known age is applied to that portion of their lives between the first capture and subsequent recaptures. The intervals between captures ranged from approximately 1 to 26 months; some fish were recaptured as many as 5 times.

METHODS AND SOURCES OF SCALE SAMPLES

All scale samples from known-age wild trout were obtained from specimens captured during a study of fish populations and movements carried out by the Montana Fish and Game Department on Prickley Pear Creek, Lewis and Clark County, Montana (Stefanich 1952). A detailed description of the study area is reported by Stefanich. Scale samples totaling 1,055 were taken from recaptured wild trout during the period from June 1949 to October 1951 (Table 1).

Records of trout planted in Prickley Pear Creek previous to this study were as follows (average length in parentheses): 23,800 brown trout (1.5 inches) on June 3, 1948, 3,150 brook trout (3 inches) on June 19, 1947; 28,000 brown trout (1.5 inches) on June 4, 1947; and 34,320 brown trout (advanced fry) on June 11, 1946. Some of these planted fish may have been included among fish listed here as wild. In any event, such fish would have been in the stream at least 1 year before capture in 1949. The following four plants of hatchery-reared rainbow trout were made in Prickley Pear Creek during the period of study: 2,955 fingerlings (3½ inches) on September 8, 1949; 811 yearlings (6 inches) on May 13, 1950; 3,000 fingerlings (3 inches) on September 17, 1950, and 997 yearlings (6 inches) on May 17, 1951. A total of 129 scale samples were taken from recaptured, hatchery-reared rainbow trout in 1950 and 1951.

Most of the scale samples from Prickley Pear Creek were from trout captured with an A. C. electric shocker. Only 51 samples were secured from trout caught by fishermen. "Shocked" fish were anesthetized in a solution of urethane, and when sufficiently calmed, were weighed, measured (total length), and scale samples taken. After the fish recuperated in holding cages, they were released in the area from which they were captured. Wild trout, when first captured, were marked with numbered, metal jaw tags and scale samples were taken. Scale samples were taken once each collection period at the time of recapture on all recaptured trout from November 1949 to October 1951.

Scale samples were removed from the fish in the area between the dorsal

TABLE 1.—Number of scale samples from wild trout recaptured from Prickley Pear Creek during the period June 1949 to October 1951

Item	1949		1950					1951					Totals
	Number of recaptures		Number of recaptures					Number of recaptures					
	1		1	2	3		1	2	3	4	5		
Brown trout													
Number of trout	..		106	43	16		29	13	19	15	3	244	
Number of scale samples ¹ . . .	..		212	129	64		58	39	76	75	18	671	
Rainbow trout													
Number of trout	2		84	23	3		26	10	4	2	1	153	
Number of scale samples ¹ . . .	4		168	69	12		52	30	16	10	6	363	
Brook trout													
Number of trout	..		6	1	..		3	..	..	..	..	10	
Number of scale samples ¹ . . .	..		12	3	..		6	..	..	..	..	21	
Totals													
Number of trout	2		196	67	19		58	23	23	17	4	407	
Number of scale samples ¹ . . .	4		392	201	76		116	69	92	85	24	1055	

First capture is added to recapture for totals of scale samples

fin and the lateral line. To minimize the number of regenerated scales taken, this area was divided into 3 sections on each side as follows: below the anterior one-third, below the middle one-third, and below the posterior one-third of the dorsal fin. On first capture, all scale samples were taken on the left side of the fish below the anterior one-third of the dorsal fin. On recaptured fish a different section was used for each collection period.

Hatchery trout planted in Prickley Pear Creek during the period of study were identified by clipping the adipose and either the right or left pelvic fin. These fish were collected at the same time and were handled in the same manner as wild trout.

Savage Lake (Lincoln County, Montana) received a plant of 50,000 rainbow trout fry on March 18, 1949. The lake had been previously poisoned on August 23, 1948, and practically all of the fish removed. Scale samples were obtained through angling from 3 of the planted fish during 1949, 52 during 1950, and 14 in 1951.

Scale samples were collected from 63 known-age rainbow trout taken from the brood ponds at the U. S. Fish and Wildlife Service Fish Hatchery, Ennis, Montana. These fish represented 5 different year classes, each of which could be identified by a combination of clipped fins. The water temperature of the ponds in which the brood stock was held ranged from 45° to 55° F. throughout the year. All scale samples taken from 21 of the brood trout were regenerated, probably as a result of handling during spawning operations.

In this study, six good scales from each fish, if available, were mounted on glass slides in a gum-arabic medium. Scale images were examined on a conventional type projector and the position of the annuli along the anterior radius of the scale were marked on heavy paper strips. At the same time, counts of circuli were made and any obvious irregularities in scale characters were noted.

Some of the scales were photographed in order to facilitate more minute comparisons of scale characters. Photographs also permitted simultaneous viewing of scales taken at different times from the same fish.

Annuli were determined by the usual characters of "cutting over", packing of circuli, and irregularities associated with a change in growth of the scale. Some scales lacked a band of closely spaced circuli (Fig. 1a); in others, the peripheral area was so jumbled that interpretation was impossible (Fig. 1b). In general, annuli on the scales of older trout became less definite beyond the third year; their close proximity to one another in the outer region of the scale made interpretation difficult. Erosion or resorption obliterated scale characters in many scales (Fig. 1c).

SCALE CHARACTERS ON WILD TROUT TAGGED AND RECAPTURED IN PRICKLEY PEAR CREEK

The estimation of the validity of annuli as indicators of age was based on the comparison of scales collected in the fall of one year with scales from the same fish recaptured the next season at a time after the addition of an annulus would be expected (Table 2). For age-groups 0 to II of the

TABLE 2.—Annulus formation on scales of trout from Prickley Pear Creek, based on comparisons of scales taken from the same fish in the fall of one year and in the summer or fall of the next year

Age group at time of capture	Scales taken November 24-27, 1949					Scales taken September 18-25, 1950					
	Recaptured: June 22-30, 1950			Recaptured September 18-25, 1950		Recaptured July 7-18, 1951			Recaptured September 6-14, 1951		
	Number with annuli	Number without annuli	Percentage without annuli	Number with annuli	Number without annuli	Number with annuli	Number without annuli	Percentage without annuli	Number with annuli	Number without annuli	Percentage without annuli
Brown trout											
0	4	1	20.0	12	..	2	..	0.0	4	..	0.0
I	40	..	0.0	61	..	4	..	0.0	7	..	0.0
II	17	1	5.6	26	..	21	..	0.0	28	..	0.0
III	16	10	38.5	28	15	4	5	34.9	6	5	45.5
IV	6	9	60.0	8	13	3	8	61.9	6	9	60.0
V	1	2	66.7	1	3	..	..	75.0	..	1	100.0
Totals	84	23	21.5	136	31	34	13	18.6	51	15	22.7
Rainbow trout											
0	1	..	0.0	1	..	..	..	0.0	1	..	0.0
I	12	1	7.7	21	1	8	..	4.5	16	..	0.0
II	11	1	8.3	17	1	2	2	5.6	3	2	40.0
III	1	..	0.0	2	..	1	1	0.0	1	1	50.0
IV	..	1	100.0	..	2	..	..	100.0	..	..	0.0
Totals	25	3	10.7	41	4	11	3	8.9	21	3	12.5
Brook trout											
I	1	..	0.0	1	..	..	..	0.0	..	..	0.0
II	1	..	0.0	1	1	..	..	50.0	..	..	0.0
Totals	2	..	0.0	2	1	..	..	33.3	..	..	0.0

brown trout the expected annulus was present in 61 of 63 fish captured June 22–30, 1950, and on all of 27 captured July 7–18, 1951. All fish of these age groups had formed new annuli by September 18–25, 1950, and September 6–14, 1951. The situation was much different in the older age groups (III to V). In the June 22–30, 1950, collection, 21 of 44 brown trout or 47.7 percent; and in the July 7–18, 1951, collection, 13 of 20 fish or 65.0 percent had failed to form the expected annulus. It cannot be assumed that failure of so many of these older fish to show annuli was the result of their capture early in the season, because the percentages of scales without annuli were high also in later collections of the same years. On September 18–25, 1950, 31 of 68 fish or 45.6 percent were still without annuli (this figure is only slightly below the percentage of 47.7 percent on June 22–30) and on September 6–14, 1951, 15 of 27 fish or 55.6 percent lacked the expected annuli (compared with 65.0 percent for July 7–18). It is not likely that these older fish would form annuli after September collection dates.

The data of Table 2 therefore, lead to the general conclusion that among younger brown trout scale readings are dependable indicators of age, but that many older fish (probably about half) fail to complete discernible annuli. The situation seems to be similar for rainbow trout, although the older age groups were poorly represented. The data on brook trout are too scanty to warrant conclusions.

The question now arises as to whether the conclusions based on Table 2 hold for "natural" populations of wild trout. Conceivably, the tagging and handling at capture and recapture may have affected the fish so ad-

Explanation of Figure 1

a. Scale taken in June 1950 from a Prickley Pear Creek brown trout. The second annulus lacks a band of closely spaced circuli.

b. Scale taken in July 1949 from a brown trout which measured 15.7 inches in total length. A jumbled peripheral area is shown.

c. Scale from a Prickley Pear Creek brown trout, showing the obliteration of scale characters by erosion or absorption.

d. Brown trout scales from Prickley Pear Creek showing a check mark (c). This check mark was present in the same relative position on 3 other scales taken at different times from the same fish.

e. Scale taken in May 1950 from a yearling rainbow trout which had been held in the hatchery. Check mark (c) is shown.

f. Scale from a rainbow trout of the same group of fish as in e but planted as a fingerling in Prickey Pear Creek in September 1949 and collected in August 1950. The annulus is shown in much the same position as the check mark on the scale in e.

g. Scale from a rainbow trout planted in Prickley Pear Creek as a yearling in May 1950 and collected in June 1950. Check marks (c) are shown.

h. Scale from a rainbow trout fingerling planted in Prickley Pear Creek in September 1950 and collected in November 1950. Several closely spaced circuli are shown on the edge of the scale.

i. Scale from a rainbow trout planted as a fry in Savage Lake in March 1949 and collected in August 1949 at a length of 8 inches. Growth was fast and uniform.

j. Scale from a rainbow trout of the same Savage Lake plant as in i, but collected in May 1951. One annulus is shown.

k, l. Scales taken May 1950 from rainbow trout brood stock (1948 hatch) at the Ennis Hatchery. Varying number of "annuli" (f) are shown.

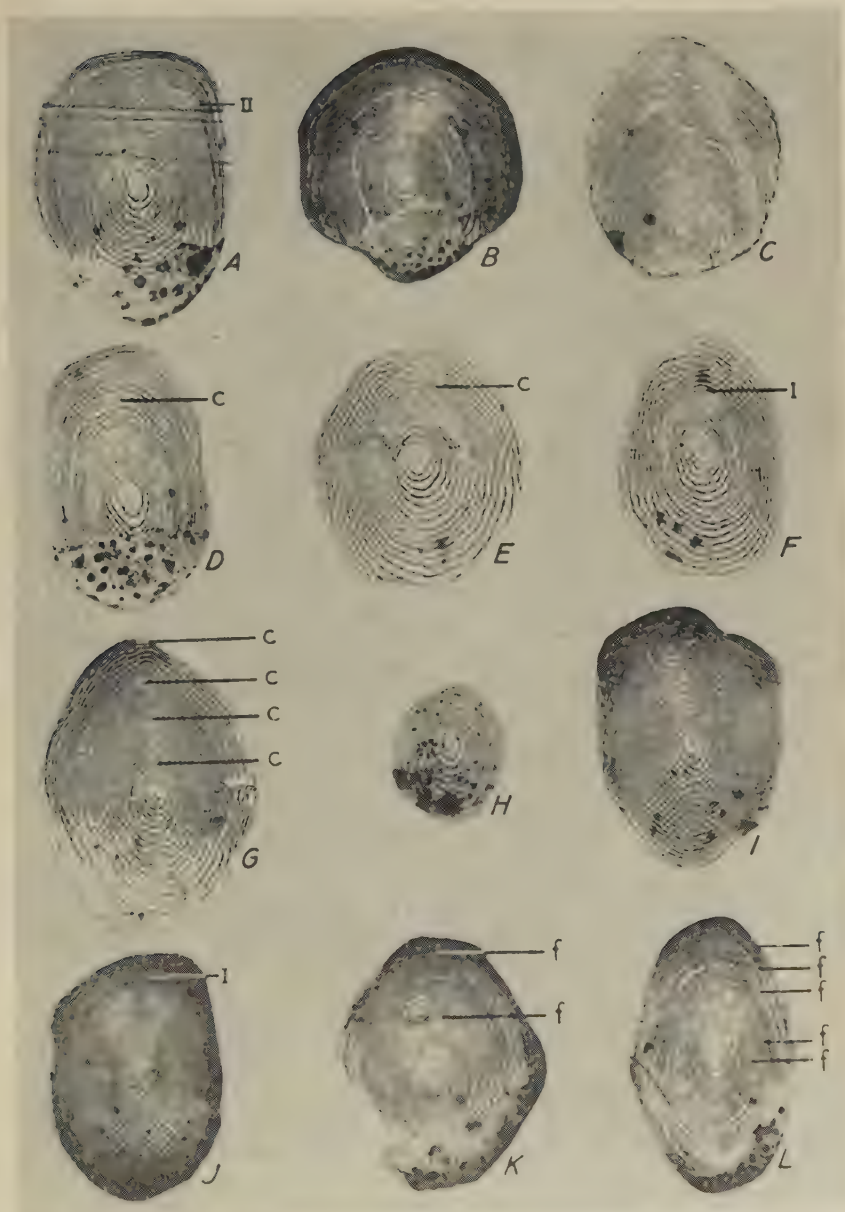


FIGURE 1

versely that many of the older individuals which would have formed annuli under "normal" circumstances failed to do so under experimental conditions. This problem was approached through a study of the relationship between growth after tagging and incidence of annulus formation in the experimental fish (Table 3), and through a comparison of the growth of tagged and wild trout (Table 4). In addition, an inquiry was made into the relationship between the increase in fish length and the increase in number of circuli on scales, in order to estimate the amount of fish growth necessary for new growth to be detectable from their scales.

Gains in the number of circuli were determined by averaging the counts of the total number of circuli from the focus to the anterior edge of the scale for all of the scales mounted on the slide (usually 6 scales). In the comparisons between gains in the number of scale circuli and increases in total body length (detailed data not given here) age of the fish was not found to influence the number of circuli formed; growth alone was responsible. Although the relationship between total length gain and increase in number of scale circuli varied considerably among individual fish, averages brought out clear-cut trends. Averages for the brown trout and rainbow trout were similar and showed one circulus formed for approximately each 0.2 inch gain in total body length.

Because of the great variability of scale size, even within a limited body area, an inquiry into the relationship between increase in scale radius and increase in fish length proved unprofitable.

Failure to form annuli was almost always accomplished by little or no increase in total length, and occurred, for the most part, in older fish (3 years or over). Total length gains of less than 0.8 inch between growing seasons were found in 69 brown trout, 15 rainbow trout, and 2 brook trout. In these slowly growing fish the expected new annulus was lacking in 59.4 percent of the brown trout, 33.3 percent of the rainbow trout, and 50.0 percent of the brook trout (Table 3). Seven of the brown trout and 3 of the rainbow trout in the slowly growing group had either sore mouths, due to jaw-tag irritation, or deformed backs, probably resulting from the effect of electric shocking. Eight of these 10 fish failed to form annuli during the expected annulus-formation periods. In all trout combined 219 had gained more than 0.8 between growing seasons; only 3.7 percent of this group failed to form new annuli as expected.

EFFECTS OF SHOCKING, HANDLING, AND TAGGING OF TROUT ON THEIR SCALE CHARACTERS

Comparisons between average total lengths of tagged wild trout which had been recaptured, and average total lengths of wild trout captured only once (Table 4) revealed greatest differences between total lengths of recaptured trout and wild trout in the older age groups, especially in the brown trout. The slower growth rate of the older tagged brown trout was reflected in the close proximity of annuli on the outer edges of the scales and the failure, in some fish, to form new annuli.

Average total length within age groups for the tagged wild rainbow trout

TABLE 3.—*Relationship between annulus formation and gain in total length*

Increase in total length (inches)	Scales taken November 24-27, 1949						Scales taken September 18-25, 1950					
	Recaptured June 22-30, 1950			Recaptured September 18-25, 1950			Recaptured July 7-18, 1951			Recaptured September 6-14, 1951		
	Number with annuli	Number without annuli	Percentage without annuli	Number with annuli	Number without annuli	Percentage without annuli	Number with annuli	Number without annuli	Percentage without annuli	Number with annuli	Number without annuli	Percentage without annuli
Brown trout												
Less than 0.8	7	21	75.0	24	29	54.7	4	10	71.4	4	12	16.7
Greater than 0.8	77	2	2.5	112	2	1.8	30	3	9.1	47	3	6.0
Rainbow trout												
Less than 0.8	9	3	25.0	9	4	30.8	1	1	50.0	1	1	50.0
Greater than 0.8	16	..	0.0	32	1	3.0	10	2	16.7	20	2	15.1
Brook trout												
Less than 0.8	1	..	0.0	1	1	50.0	..	..	0.0	..	..	0.0
Greater than 0.8	1	..	0.0	1	..	0.0	..	..	0.0	..	..	0.0

TABLE 4.—Average total length (inches) of marked and wild Prickley Pear Creek trout at time of capture

Collection Period	Age-group 0 ¹		Age-group I		Age-group II		Age-group III		Age-group IV	
	Recaptured	Wild ²	Recaptured	Wild	Recaptured	Wild	Recaptured	Wild	Recaptured	Wild
Brown trout										
June 22 July 13, 1949.....	...	2.9	5.5	5.6	8.3	8.3	11.0	11.4	13.8	14.0
August 11-17, 1949.....	3.6	3.3	6.4	6.2	8.8	8.0	11.9	12.3	13.9	15.8
September 16-23, 1949.....	3.9	4.0	6.8	6.6	9.3	10.1	12.2	13.5	...	13.2
November 24-27, 1949.....	4.2	4.2	6.3	7.1	...	10.4	10.9	12.3	...	15.2
June 22-30, 1950.....	3.8	...	4.9	4.9	7.8	7.7	10.8	12.2	...	13.8
August 7-15, 1950.....	...	2.1	5.8	5.7	8.3	9.7	10.9	12.3	12.9	16.1
September 18-25, 1950.....	3.9	3.7	6.3	6.4	8.8	11.1	11.0	11.8	12.8	13.8
July 7-18, 1951.....	...	...	5.0	5.0	7.8	8.0	10.5	11.7	13.3	13.3
September 6-14, 1951.....	...	3.5	6.0	6.2	8.5	9.2	10.5	12.3	13.2	13.6
Rainbow trout										
June 22-July 13, 1949.....	...	...	5.2	5.4	8.4	8.1	10.0	10.9	12.3	12.5
August 11-17, 1949.....	...	2.7	6.3	6.1	9.6	9.2	...	11.0	...	10.4
September 16-23, 1949.....	...	3.5	6.7	6.3	9.5	8.6	...	11.9	...	...
November 24-27, 1949.....	4.1	3.8	6.6	6.9	9.3	9.8	...	12.8	...	...
June 22-30, 1950.....	...	...	4.7	4.6	7.5	7.1	10.1	8.5	11.2	...
August 7-15, 1950.....	...	...	5.8	5.8	8.1	8.9	10.9	10.4	11.9	...
September 18-25, 1950.....	4.9	3.6	6.4	6.2	8.4	9.0	11.1	11.0	11.8	...
July 7-18, 1951.....	4.0	...	5.2	4.8	7.6	7.7	10.1	9.7	9.8	15.4
September 6-14, 1951.....	...	2.9	6.3	6.6	8.3	9.6	10.0	9.0	12.8	...

¹ No annulus at time of collection² From Bishop, Clinton G., 1953, Age, growth, and condition of trout in Prickley Pear Creek, Montana. Unpublished thesis, Montana State College

were similar to those of wild rainbow trout captured only once. Apparently the rainbow trout were less affected by the shocking, handling, and tagging than were the brown trout.

"Check-marks" which may have been caused by shocking, handling, and tagging were present on some scales (Fig. 2d). These marks, however, did not occur with any regularity, but were peculiar to the individual fish rather than characteristic of groups.

SCALE CHARACTERS OF HATCHERY-REARED RAINBOW TROUT PLANTED IN PRICKLEY PEAR CREEK

From a group of rainbow trout fingerlings fin-clipped on September 8, 1949, 2,955 were planted in Prickley Pear Creek on the same date and 100 were retained in the hatchery to determine the extent of fin regeneration. Scales taken May 3, 1950, from the fish held in the hatchery exhibited a "check-mark" (Fig. 2e) similar in position to the annulus (Fig. 2f) on scales taken August 10, 1950, from fish of the same original group that were planted in Prickley Pear Creek. Scales taken on July 9, 1951, from recaptured trout of the same plant showed 2 annuli and growth beyond. There was no discernible difference between scales of the planted trout and scales of wild trout of the same age and size.

Yearling rainbow trout which averaged 6 inches in total length were planted in Prickley Pear Creek on May 3, 1950. Scales taken from these fish on June 17, 1950, had closely spaced circuli near the outer edges and exhibited 2 to 4 "check-marks" (Fig. 2g). Scales from most wild trout collected at this time had new annuli and several widely spaced circuli beyond. Miller (1952) found that planted trout did not begin eating for about 40 days, and Bhatia (1932) produced so-called "annual zones" on the scales of trout by altering the food supplies of the fish. These findings may explain in part, the slow growth of the scales of planted yearling fish.

Young-of-the-year rainbow trout which averaged 3 inches in total length were planted in Prickley Pear Creek on September 17, 1950. On November 24, 1950, scales from these fish had closely spaced circuli near the edges (Fig. 2h). Scales taken September 11, 1951, from trout of this plant had one annulus and average growth beyond.

Scales from yearling rainbow trout planted May 17, 1951, in Prickley Pear Creek had as many as 4 "check-marks" when collected July 17, 1951. These marks lacked most characteristics of annuli. As with yearling rainbow trout planted in 1950, circuli were more closely packed on the outer edges of their scales.

In general, the scales from planted yearling rainbow trout exhibited variable "check-marks" which made interpretation, with any degree of certainty, impossible. Scales from rainbow trout planted as fingerlings, however, could not be distinguished from the scales of wild trout of the same size, collected at the same time.

SCALE CHARACTERS OF RAINBOW TROUT PLANTED IN SAVAGE LAKE

Rainbow trout fry were planted in Savage Lake on March 18, 1949. These fish were over 8 inches long by August 26, 1949, when scales were taken. This rather exceptional growth was reflected in the scales which had widely spaced circuli with almost no irregularities (Fig. 2i). By June 25, 1950, the total length of these trout ranged from 9.3 to 11.0 inches. Scales taken at this time exhibited one annulus and new growth beyond. When scales were taken again on August 1, 1950, the only change was additional growth beyond the annulus. The last scale samples were taken from the Savage Lake rainbow trout, May 7, 1951; the second annulus had not yet formed at this time (Fig. 2j).

SCALE CHARACTERS OF THE ENNIS HATCHERY RAINBOW TROUT

"Annuli" on the scales of Ennis Hatchery rainbow trout brood stock did not conform to the known age of the fish, nor did they always appear in similar positions on the scales of trout of the same age. Scales from trout hatched in 1948 had from 2 to 5 annuli in May 1950 (Fig. 1k and 1l). Scales from trout hatched in 1947, taken at the same time, were equally as varied as to number of annuli, and could only be distinguished from the other trout by the clipped fins. Since temperatures of the ponds in which the brood stock was held remained nearly constant throughout the year, the "annuli" probably resulted from feeding practices and handling of the fish during spawning operations.

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James Drummond of the Montana State College Wood Laboratory made available microprojection and photographic facilities.

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BIO-ASSAY PROCEDURES FOR THE EVALUATION OF FISH TOXICANTS WITH PARTICULAR REFERENCE TO ROTENONE¹

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ABSTRACT

The effects of variations in volume of solution of toxicant, aggregation, temperature, and change in condition of test animals during time of holding in the laboratory were investigated with regard to possible influences on bio-assay results. The western gambusia, *Gambusia affinis affinis* (Baird and Girard) was used as the test animal. In spite of relatively favorable experimental conditions, it seems that estimates of relative toxicity are affected by uncontrolled variations which greatly limit dependability.

The relative stability of toxicity indices based on simultaneous comparisons of a standard with test materials was demonstrated. Although the advantages and possible limitations of the toxicity index were not fully explored, the procedure appeared to produce a consistency of results not previously encountered. Factors which may affect toxicity index values remain to be evaluated in bio-assay procedures with fish. However, some indication has already been given of the usefulness of this concept.

INTRODUCTION

Bio-assay procedures are important to aquatic biologists in the evaluation of acute toxicity, not only of industrial wastes and other pollutants, but of materials of possible use in controlling fish populations as well. Some obvious difficulties in obtaining consistently reliable bio-assay results are evident when one considers the inevitable variations in environmental conditions and resistance of test animals. It seems, however, that attempts to obtain more reliable data by measuring the effects of certain variables and by applying simple quantitative methods to toxicity studies which involve aquatic organisms have not received sufficient attention. The purpose of this paper is to consider the effects of variations in some physical and biological conditions on results of bio-assays with fish, as well as to apply methods which appear to approach more nearly the objective of consistently reproducible results.

EXPERIMENTAL PROCEDURES

The toxicants used were pure rotenone (molecular weight 394) and commercial products containing rotenone with or without synergists.² For

¹ Contribution No. 539 from the Department of Zoology, Indiana University. Present address of author—R. I. Division of Fish and Game, Veterans' Memorial Bldg., Providence 2, R. I.

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these tests western gambusia were obtained from a single hatchery pond near Bloomington, Indiana, in an attempt to limit the effects of genetic and gross environmental differences to the extent possible. Only fish of about 30 millimeters standard length were selected. Bloomington city water, aerated for at least 12 hours prior to the experiments, was used. No aeration was supplied during the experiments because significant reductions in dissolved oxygen were not observed during several preliminary trials. Glass aquaria with iron frames were employed; each contained 10 fish in 40 liters of test material unless otherwise specified. Experimental justification for this number and volume is given. Stock solutions of test materials were prepared immediately prior to experimental dilution unless stated otherwise. Controls were run for each series of experiments but showed no mortality during the test periods. The short duration of all experiments minimized the importance of control tanks. The general principles outlined by Douderoff *et al.* (1951) for the care and handling of fishes were followed. The conditions under which individual experiments were performed will be briefly mentioned since they were necessarily somewhat variable.

The derivation of median tolerance limits by the straight-line graphical method described by Douderoff *et al.* (1951) did not seem satisfactory for the purposes at hand since no indications of the experimental variation are afforded. Hence, comparisons seemed rather meaningless in view of the recognized heterogeneity of bio-assay results. A cursory study of the literature reveals that several solutions of the dose-percent effect curve have been derived by conversions of dose to logarithms and percent effect to probits by Bliss (1938), to logits by Berkson (1946), or angles by Knudsen and Curtis (1947). These methods unfortunately do not lend themselves to easy computation by the average biologist with limited time and facilities. On the other hand, several approximate solutions to this curve have also been developed. A graphic method outlined by Litchfield and Wilcoxon (1949) is utilized in this paper. This method permits rapid estimation of confidence limits for the median lethal dose³ (or any other desired dose) as well as for the slope of the dose-percent effect curve. Further justification for this method was given by Eisenberg (1952) who showed that the graphic method used herein will not underestimate the size of confidence intervals obtained by the standard method of Bliss.

The sources and derivation of formulas used in the Litchfield-Wilcoxon method are well described by the authors. In brief, the procedure involves plotting doses against percent effect on logarithmic probability paper (Codex 3228). The chi-square method is used to test the goodness-of-fit of a line drawn through the points obtained. If the data are significantly heterogeneous, confidence limits may be corrected for degree of heterogeneity. A rapid test for parallelism between two curves is provided as well as a method for easy computation of relative potency with the confidence limits.

³ Dose refers to actual survival time (expressed in minutes) or to the concentration of test material (expressed in milligrams per liter) in this paper.

EFFECTS OF CERTAIN FACTORS ON THE EVALUATION OF BIO-ASSAY TESTS

Volume.—The importance of determining an optimum volume or rate of flow for each test material has been demonstrated by Prévost, Lanouette, and Grenier (1948). These authors suggested that an optimum volume be determined for each material and test animal used in toxicity studies.

The results of an experiment in which all conditions except the volume of test solution were similar are shown in Figure 1. In this experiment, test fish were simultaneously exposed to the same concentration of pure rotenone at three different volumes. A significant difference at the 5-percent level is demonstrated between the speed of action with 10 fish in 5 liters as compared to 10 fish in 40 liters of test sample. A potency ratio of 1.8 with 95-percent confidence limits of 1.0–3.2 were determined for these two volumes.⁴ Differences between volumes of 10 and 40 liters containing equal numbers of fish were also significant as can be seen from the figure. The apparent anomaly in the locations of the lines for 10 and 5 liters is attributed to uncontrolled experimental variation. Actually, differences between these two lines are non-significant at the 5-percent level. In a second experiment 80, 40, and 20 liters of test solution were used. No significant differences in relative potencies, as measured by median survival time, occurred between any of these volumes.

A fourfold increase in volume (1 to 4 liters per fish) appeared to increase relative potency by a factor of more than 1.8. These data suggest that the lower limit of an optimum volume within the range tested is about 20 liters per 10 fish. For subsequent experiments 40 liters of test material for each 10 fish, which is well above the lower limit, was chosen as a convenient optimum volume.

Aggregation.—Allee (1931) suggested that aggregation may have an effect on animal behavior, and this was considered a possible factor in bio-assay results. An experiment was performed to determine whether groups of fish might respond differently than individuals. As illustrated in Figure 2, no significant difference in the speed of action of pure rotenone at 0.04 milligram per liter was found when 10 fish, each in 4 liters of solution were simultaneously compared with 10 fish aggregated in 40 liters of toxicant. Of course no broad generalizations can be made from this observation, but it seemed reasonable to surmise that that several fish could be used in a single tank within the range of a previously determined optimum volume.

Temperature.—An appreciation of temperature effects on bio-assay procedures involving fish is of extreme importance. Desavelle and Hubault (1951) have already pointed out that some mineral acids have a positive temperature coefficient of toxicity whereas the relative toxicity of ammonia depends on concentration only within a fairly broad temperature range. Gersdorff (1943), using goldfish as the test animal, demonstrated a positive temperature coefficient of toxicity for rotenone and phenol. Investiga-

⁴ Potency ratio refers to the quotient obtained by dividing the larger median lethal dose by the smaller.

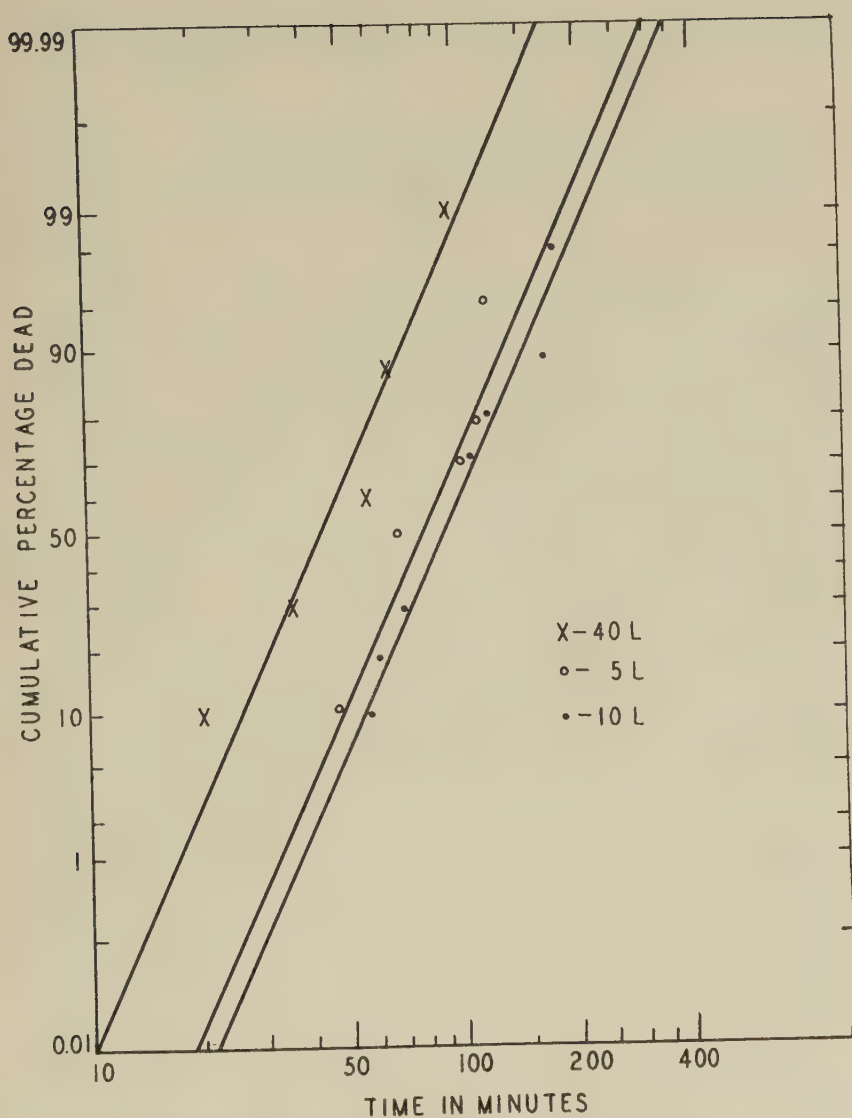


FIGURE 1.—Effects of different volumes (liters per 10 fish) of pure rotenone at 0.04 milligram per liter on speed of action at 22°–23° C.

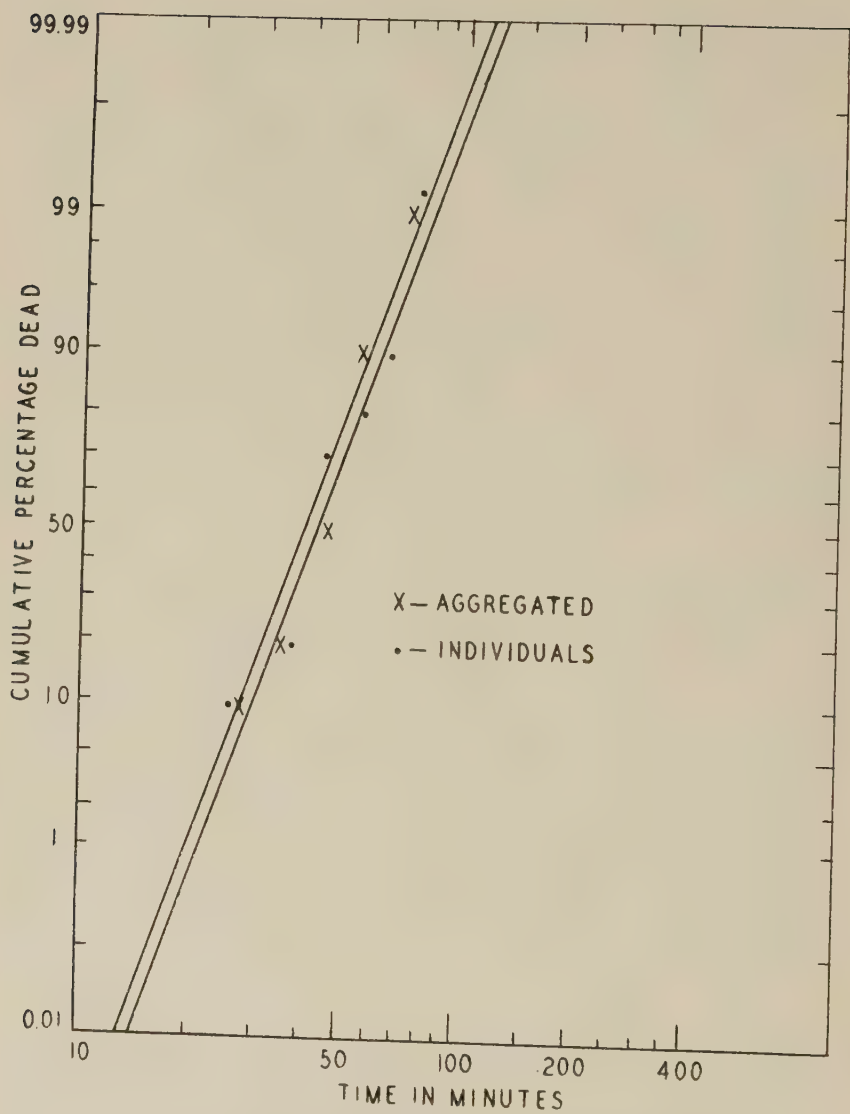


FIGURE 2.—Comparison of the speed of action of 0.04 milligram per liter of pure rotenone on aggregated fish and individuals at 22.5°–23.5°C.

tors of insecticides have also demonstrated that some materials (DDT, for example) have negative coefficients. There appears to be no way of predicting temperature coefficients of toxicity. They must be determined by experimentation.

In an experiment illustrated by Figure 3, relative toxicity increased by a factor 1.6 (95-percent confidence limits of 1.3–1.9) for a 5°C. increase in temperature. This finding agrees closely with a value of 1.66 for goldfish which was determined in a different manner by Gersdorff (1943). Rigorous control of temperature in comparisons of relative toxicity as well as a knowledge of the effects of temperature gradients are essential in bio-assay procedures.

Resistance of fishes.—Careful instructions for feeding, holding, and handling test animals have been included in most directions for bio-assay procedures. Laboratory conditioning is often suggested, presumably with the idea that test animals will be in a reasonably stable physiological condition for the duration of the experiments. Figure 4 gives some indication of the changes in resistance of gambusia which were held in the laboratory for various lengths of time before they were subjected to experiments. These fish were maintained under as nearly suitable conditions as could be established in aerated aquaria. This figure shows a more than sixfold decrease in median survival times over a period slightly more than a week. The decrease in resistance was roughly proportional to the length of time the fish were held over the test period. In this instance, broad assumptions regarding a stable physiological state are probably not justified.

The effect of some simple physical and biological variables were measured by the bio-assay method. Unfortunate combinations of these conditions could produce great variations in results even if the same test material were used over a period of time. Other possible sources of variability might include differences in dissolved oxygen or carbon dioxide content of the test solution, alkalinity, as well as size, and genetic or age differences of the test animals.

The importance accorded to the standardization of procedures and rigid control of experimental conditions does not appear to have been over-emphasized. However, one might still question results of relative toxicity determinations made under apparently controlled conditions in the light of what has been suggested by the data presented. The need for a more stable criterion of toxicity is quite evident. The difficulty of interpretation of bio-assay results obtained from a practical problem can be illustrated by an experiment conducted to determine possible loss of toxicity of rotenone during storage. Some knowledge of the extent of loss of toxicity of commercial products containing rotenone is important to fishery biologists. Although chemical methods are available for the determination of rotenone and allied compounds in commercial products and in water, these methods are not particularly helpful in determining loss in toxicity by storage. It was thought that a bio-assay might be useful in an instance such as this.

A stock solution containing 1,000 milligrams of rotenone per liter was prepared from 5-percent emulsifiable rotenone. An aliquot was removed and

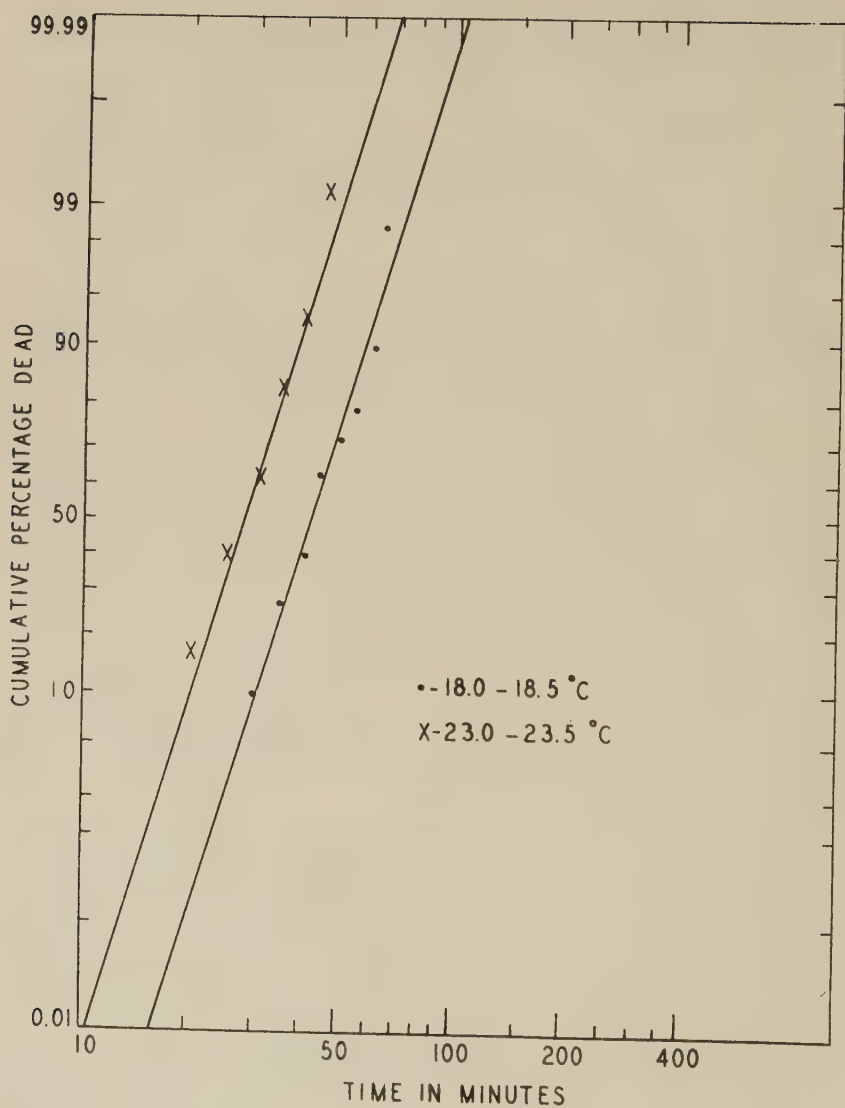


FIGURE 3.—Effect of temperature on speed of action of emulsifiable rotenone (0.0125 milligram per liter expressed as pure rotenone).

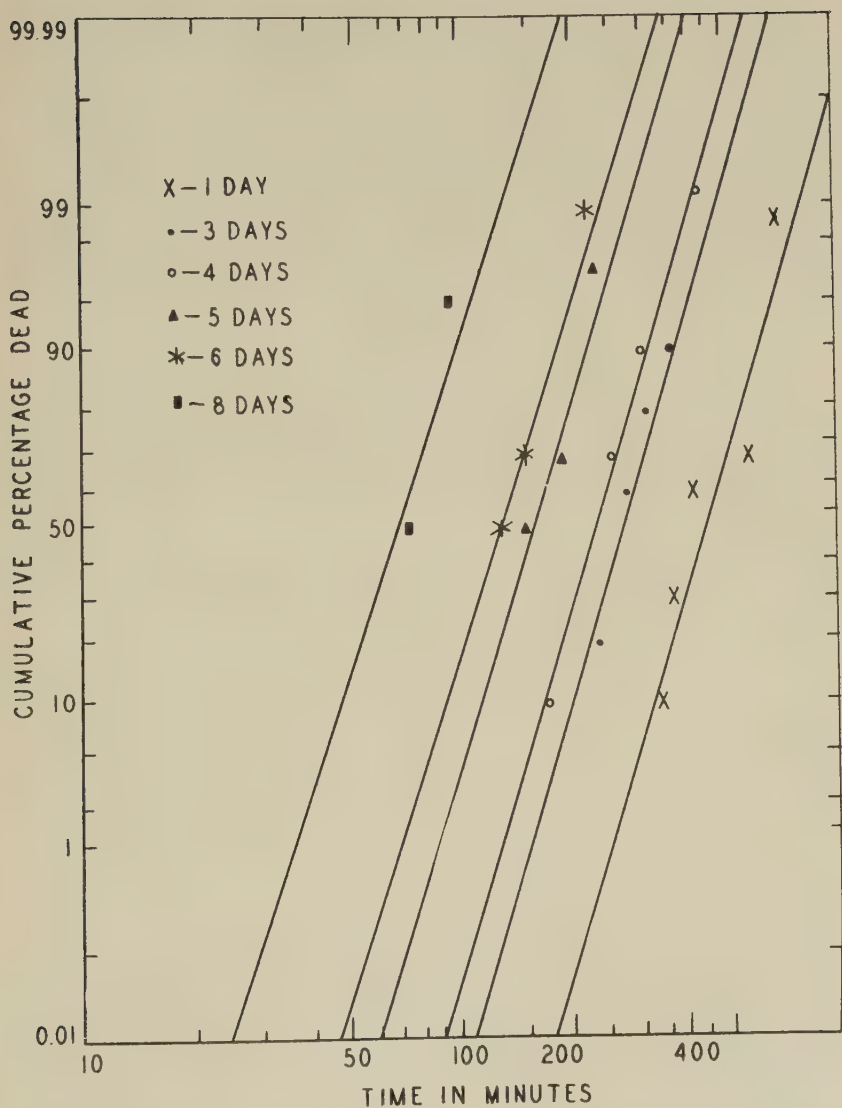


FIGURE 4.—Effects of length of time fish are held in the laboratory on the resistance of gambusia to 0.03 milligram per liter of pure rotenone.

its relative toxicity determined. A median lethal dose of 0.0125 milligram per liter with 95-percent confidence limits of 0.0108–0.0145 was found at this time. The stock solution was then stored on an open laboratory shelf for 33 days in a flask which was lightly stoppered with a cotton plug. After storage, the median lethal dose of another aliquot was determined to be 0.0200 milligram per liter with 95-percent confidence limits of 0.0156–0.0256. From these data it appears evident that there was an appreciable loss in toxicity over time—the same material was apparently 1.6 (with 95-percent confidence limits of 1.2–2.2) times more toxic before storage. This difference in potency ratio could have resulted either from a real loss in toxicity with time or, as discussed above, from minor variations in experimental conditions. A better method of evaluating this problem is by the toxicity index.

TOXICITY INDEX

The concept of toxicity index is not entirely new, but its merits have only recently been demonstrated in insect toxicology by Sun (1950). Toxicity index is defined by Sun as the ratio between the median lethal dose of a standard test material and that of a test sample multiplied by 100. The toxicity index of the standard test material used in any case is always taken as 100.

TABLE 1.—Comparison of relative toxicity and toxicity index values for samples of 5-percent emulsifiable rotenone before and after storage (33 days)

Toxicant	Concentration required for 50-percent mortality		Toxicity index ¹	
	Before storage	After storage	Before storage	After storage
Pure rotenone (standard)	0.0190	0.0310	100	100
Emulsifiable rotenone (5 percent)	0.0125	0.0200	152	155

$$^1 \text{ Toxicity index} = \frac{\text{Median lethal dose of standard}}{\text{Median lethal dose of test sample}} \times 100$$

An application of toxicity-index values was made to the problem of rotenone storage. By definition, it is necessary to compare simultaneously the test material with a standard, preferably of the same composition as the test material. In this experiment freshly dissolved and diluted pure rotenone was used as a standard against the stock mixture of emulsifiable material. It is recognized that pure rotenone is relatively stable in the crystalline state; hence, its use seemed justified. The results of comparing the test material (5-percent emulsifiable rotenone) with a standard before and after storage and the derived toxicity index values (Table 1) make it obvious, without any test of significance, that the toxicity indices of 152 and 155 are nearly identical. When the index values are somewhat more

discrepant, however, these values may be compared by a simple chi-square test. According to the toxicity-index values there was no change in the potency of the stock solution during storage for 33 days.

It is apparent from Table 1 that the consistency in the determination of toxicity indices is based on the fact that change in the median lethal dose of a test sample is accompanied by a proportional change in the median lethal dose of the standard. It would appear, then, that some variations in biological factors, such as those affecting resistance of fish, have no appreciable effect on toxicity index values. Since changes in the standard and test material are theoretically proportional for different conditions, no significant changes in toxicity indices may be expected from physical factors, such as variation in volume of test solution or temperature. Although further experimental data are needed to define more precisely the conditions under which toxicity indices remain stable, some advantage in their use has already been pointed out.

TABLE 2. —Comparison of toxicity indices obtained by direct and indirect calculation

Toxicant	Toxicity index by direct calculation	Toxicity index by indirect calculation	Standard index 100
Emulsifiable rotenone + 10-percent sulfoxide	276	286	Pure rotenone
Emulsifiable rotenone	152	...	Pure rotenone
Emulsifiable rotenone	53	...	Emulsifiable rotenone + 10-percent sulfoxide

¹ Calculations involved:

$$\frac{\text{Toxicity index of emulsifiable rotenone } 152.}{\text{Toxicity index of pure rotenone } 100} = \frac{\quad}{\quad} \text{ (Equation 1)}$$

$$\frac{\text{Toxicity index of emulsifiable rotenone } 53.}{\text{Toxicity index of emulsifiable rotenone + 10-percent sulfoxide } 100} = \frac{\quad}{\quad} \text{ (Equation 2)}$$

$$\text{Divide Equation 1 by Equation 2} = \frac{\text{emulsifiable rotenone + 10-percent sulfoxide } 286}{\text{pure rotenone } 100} = \frac{286}{100} \times 100$$

The toxicity index of one toxic material with respect to the initially chosen standard may be transferred by calculation to a toxicity index based on another standard. Table 2 shows a comparison of a toxicity index by direct calculation with that obtained by indirect calculation. The toxicity index of emulsifiable rotenone plus a sulfoxide synergist was 276 by direct calculation, with pure rotenone as a standard. To calculate the toxicity index of emulsifiable rotenone plus a sulfoxide synergist it is necessary to find the relationship between the two materials through a third—emulsifiable rotenone in this example. The simple equations from which the indirectly calculated toxicity index was obtained are also shown in Table 2. The close agreement between toxicity indices as calculated indirectly and as determined experimentally furnishes evidence of the stability of index values.

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DEPLORABLE PRESENTATION OF RESULTS OF FISHERY RESEARCH

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ABSTRACT

A large proportion of the current fishery research literature is cluttered with superfluous mathematical material, such as numbers expressed in too many significant digits or decimal places, data written more precisely than is justified by the experimental procedure, or complicated formulae and equations. This criticism applies particularly to papers published in the *Transactions* of the American Fisheries Society, a professedly practical journal. Much of this redundant matter could be omitted, with no appreciable loss in clarity or meaning; however, cases vary, and it is impossible to set any hard and fast standards of form.

INTRODUCTION

In many papers which present research data and their analysis, tendency is to be too meticulous. The reader is burdened with an amount of precision, in the form of extra digits, superfluous detail, and involved mathematics, which is of no use and little meaning to him. These statements are true of many kinds of scientific writing; but we are concerned here chiefly with articles in fishery research such as those in the *Transactions* of the American Fisheries Society. Originally the papers in the *Transactions* were written in a "practical" vein, by practical workers, and dealt with such things as the construction of rearing ponds and the benefits of introducing carp. From these subjects to the derivation of complicated formulae for calculating the body-scale relationship is a long step, and no doubt an advance; but still we must not abandon practicality. The objects of fishery research and management, now as always, are to provide and maintain good fishing and to build up a store of information about fish and their environment. Too many mathematical details can be the trees which blot out the forest.

All of the "horrible examples" in the following sections (except the one dealing with a human population) are extracted from the latest 10 volumes of the *Transactions* (Vol. 72-81). These examples are illustrative only, and their number is held to a minimum. A rough tabulation shows that about 40 percent of the some 210 technical articles in these ten volumes contain what might be termed bad usage in presenting data. Some of it is bad indeed.

Accuracy in collecting and manipulating figures (including the avoidance of computational errors) is not to be deprecated. But accuracy must not be confused with superfluity. Such details, for instance, as extra decimal

digits which cannot be significant because they are based upon figures cruder than themselves in a sense actually represent inaccuracy, for they imply a degree of precision which does not exist.

SCIENTIFICALLY UNSOUND FIGURES

Abuse of scientific soundness is encountered commonly in the expression of counts such as those of plankters in a given volume of water, minute organisms per given area of lake bottom, or eggs in a fish ovary. A count of plankton may run to, say, six digits and one of eggs in a fish ovary to five or six. When such a figure is written out to a single unit, as it sometimes is, an accuracy in visual counting is implied which simply is not feasible, whether the entire sample was counted or, as is often the case, an aliquot portion of it. And, needless to say, such accuracy is redundant. What does it matter, for all practical purposes, whether a mama fish was about ready to lay 58,644 eggs, when her progenitorial career was cut short, or 59,000?

The results of many kinds of chemical analyses often have been stated in figures which are more exact than the tests can yield accurately. An example found time and again is the free carbon dioxide content of water. As any worker should realize, who has watched for the "first appearance" or the "permanent appearance" of a "slight" pink while drop after drop of reagent is added, the end-point carries such an element of guesswork that to express the results in tenths of a p.p.m. borders on absurdity.

Similarly, total alkalinity written to the nearest tenth p.p.m., dissolved oxygen to the nearest hundredth p.p.m., and combined nitrogen to the nearest thousandth p.p.m., all probably imply greater accuracy than normally is obtainable. And it is extremely likely that such small gradations in chemical content of the water have no practical or even measurable effect upon fish or other aquatic organisms.

POOR HANDLING OF FIGURES

In this category may be placed a number of kinds of results which are capable of being measured or calculated with a certain amount of scientific precision, but which hold little or no mathematical meaning or practical significance when expressed to that degree of precision. For example, it can be computed fairly accurately that at the time of the 1950 census the average human population density of the state of New York was $0.4676 \pm$ person per acre. But to most people it really means more simply to say "about one person to every two acres."

Also in this class are those results which as presented are too voluminous, or are inconsistent in form, or ambiguous in meaning. Here are several examples of poor presentation of results:

Too many data.—A full-page table in a paper on a commercial fishery has over 300 entries, not including blank spaces, in 34 lines and 13 columns. These individual figures vary from 162 to 11,334,421 (pounds of fish). In an article dealing with catch per unit effort, there is a double-page table

with 67 lines and 16 columns. To the average reader such tables are little more than a blur. Could not the pertinent information have been presented in much more comprehensible form by one or more simple trend graphs?

Number of digits.—Distressingly common is the practice of writing too many supposedly significant digits. For example, 81,838 fish (the rounded figure 82,000 would be just as "significant" practically if not mathematically), 118,454 fry stocked per acre, 577,716 pounds of fish produced in a year, etc. Judicious rounding would be an improvement in all such cases.

However, rounding of figures is of no value unless strict consistency is adhered to. For instance, in the same line in a table appear the number 359,600 (which presumably had been rounded to the nearest 100 since several other numbers in the table were similarly rounded) and the number 49,314 which is written to the nearest unit. These numbers enter into a line total which also is carried out to the nearest unit. Now, mathematically the sum of these two numbers may be any number between 408,864 and 408,964; and will be exactly 408,914 only by chance.

Further strain is placed upon the reader's patience when needless zeros follow the decimal point, as, for example, when in a column of figures representing p.p.m. of phenolphthalein alkalinity each figure ends in .00 (obviously, determination was made only to the nearest whole number). In another example each of the totals (pounds of fish) in a long column has appended .00, although the figures from which the totals were derived are presented without any decimal encumbrances!

Decimal places.—When it comes to superfluous decimal places, the picture gets still more confusing, and the instances are greatly multiplied. A few examples are given in the following paragraphs.

The length of a fish is sometimes expressed in tenths (or even hundredths) of a millimeter or in hundredths of an inch. Certainly it is possible, by the use of precision calipers, to ascertain that a fish is exactly 10.37 inches long (or, more precisely, is between 10.365 and 10.375 inches). But just what does such a measurement mean in a planting and recovery experiment? Why would not the figure 10.4 (or in this experiment even the figure 10) do just as well? And what if the specimen dries out between measurements and shrinks a few hundredths of an inch?

In many cases, fish lengths given, say, in tenths of a millimeter represent averages rather than individuals (the individual measurements were made in whole millimeters). This procedure may be perfectly justifiable, mathematically; but it is questionable whether 146.8 millimeters for the length of an "average" fish has much more meaning than a similar figure for the length of an individual fish, when the number of fish averaged was only six, when they varied from 127 to 168 millimeters, and when all the information actually needed was the number of fish caught in a trap on a given day, and their *approximate* size.

The weight of a fish has been expressed in hundredths of a gram, or in hundredths or even thousandths of an ounce. Or the yield of fish per acre is given in hundredths of a pound. As above, even though these be average figures, the use of such small decimal fractions seems largely unjustified.

If the standing fish population of 18 streams varies all the way from 91 to 547 pounds per acre, the figure for "Dexter Creek" possesses no more meaning as 229.39 than it would as 229 pounds.

A fish weir was said to have cost \$126.06 for materials (perhaps one bolt cost six cents); yet the cost of labor and transportation was not even roughly estimated. We are told that a certain experimental body of water had a surface area of 0.131 acre. Had it been only 0.130 acre the calculated weight of its muddler population would have been about 9.75 pounds per acre instead of 9.68, a difference which hardly could have had any real bearing on the management of the stream. The average catch of crappie and bass on artificial bait per 100 fishing trips to a certain reservoir is given as 162.07 fish. Converted to average catch per fishing trip, this becomes 1.6207 fish, a horrible figure indeed (what can a fisherman do with 0.0007 fish?).

In a paper dealing with depth distribution of fish there is a table containing some 360 individual water-temperature readings, each expressed to the nearest 0.25°F . It is possible, with a fairly good field thermometer recently calibrated, to measure the true temperature with this amount of precision. However, nowhere in the article is it demonstrated that very small changes in water temperature had any measurable effect upon the depth positioning of the fish. Why, then, record and present temperature readings in such meticulous manner?

Example follows example. The coefficient of condition of fish was expressed to the nearest 0.001 when an error of one gram in weighing a 200-millimeter fish would change the value of K by about 0.012. Length conversion factors (standard length to total length) are employed to the nearest 0.0001. The coefficient of correlation (r) is written to the nearest 0.001. And so on.

Some of the most astounding examples occur in expressions of the length-weight relationship. This relationship, as it is now commonly used, takes the general form:

$$W = cL^n$$

or $\log W = \log c + n \log L$

where $W = \text{weight}$

and $L = \text{length}$

Perhaps the trouble lies in the easy access of the worker to six- or seven-place logarithm tables and in his habit of pushing the automatic-division button on an electric calculating machine and sitting back and listening to the wheels go around. At any rate, all too often there shows up in print something like this:

$$\log W = -4.625223 + 2.99278 \log L$$

the formula given for a certain sample of largemouth bass.

To demonstrate the superfluity of some of these decimal digits, let us perform some sample calculations. Suppose we let L equal 144 millimeters. The corresponding calculated value for W , given in the table in the article, is 68 grams. Calculating W , using the values of $\log c$ and n as given, and the six-place logarithm of L , we obtain the result, $W = 68.28$. Now, chop-

ping off one decimal place all the way around (i.e., using -4.62522 for $\log c$, 2.9928 for n , and the five-place logarithm of L) we find W still to equal 68.28 . Omitting another decimal place (using -4.6252 for $\log c$, 2.993 for n , and the four-place logarithm of L) we calculate $W = 68.4$. Finally, dropping a third decimal place (using -4.625 for $\log c$, 2.99 for n , and the three-place logarithm of L) we get into the slide-rule class of computation and come up with the result, $W = 67$. For many practical purposes even this last figure probably is accurate enough especially since the average empirical weight for 19 fish in this length class happened to be 67 grams.

COMPLICATED MATHEMATICS

The place of sound and thoroughgoing statistical procedure in the handling of fishery research data cannot be denied. But there is reason to believe that in many fishery writings the passion for using fancy or involved statistical formulae has run away with the writer. Complication does not necessarily denote skill. Where (or if) a line should be drawn is purely a matter of editorial policy. It seems to the present writer that many articles are unnecessarily cluttered up with formulae, equations, and derivations which render them unintelligible to the nonmathematician, and yet add little information applicable to the usual fish-management problems.

One of the most common examples of probably needlessly involved mathematics is the so-called "body-scale relationship" or the formula relating the body length of a fish to the radius or other dimension of the scale, opercle, vertebra, etc. Here complication is by diversification. There are to be found in various papers on age and growth no less than six equations expressing this relationship. These are:

- (1) $L = ar$
- (2) $L = a + br$
- (3) $L = a + br + cr^2$
- (4) $L = a + br + cr^2 + dr^3$
- (5) $L = a + br + cr^2 + dr^3 + fr^4$
- (6) $L = ar^n$

where $L =$ body length

and $r =$ radius (or diameter, etc.) of scale, opercle, etc.

Now, it well may be that different species or different populations of fish do provide data which best fit, theoretically, various curves. But, from the standpoint of practicality some degree of simplification or unification seems to be in order. The same statement can be applied aptly to many other examples.

ACKNOWLEDGMENT

Not only is the present writer but more surely are many writers of the past indebted to a host of editors, typesetters, and proofreaders who painstakingly have transcribed from typewritten manuscript to the printed page a mountain of unnecessarily detailed figures; and to the readers who have winnowed this chaff for a few kernels of pertinent information.

COMPARATIVE SURVIVAL OF WILD AND HATCHERY-REARED CUTTHROAT TROUT IN A STREAM

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ABSTRACT

Gorge Creek, a typical small mountain trout stream on the eastern slope of the Rocky Mountains, was used in a test to measure survival and weight changes in hatchery-reared cutthroat trout (*Salmo clarki*). A resident population of this species exists in the stream. The experimental procedure was to introduce groups of trout into enclosures $\frac{1}{2}$ to $\frac{3}{4}$ mile long; each trout in a group was given a numbered Petersen tag and weighed before planting. Recapture by angling and reweighing were carried out throughout the season of planting and also in later summers. In this way six lots of pond-reared, one lot of stream-reared, and one lot of transplanted wild cutthroat trout were studied. Pond-reared fish exhibited very low survivals over the first (0 to 4.9 percent) and second (0 to 3.1 percent) winter. Survival was largely independent of age. Transplanted wild trout showed survivals of 46.0 to 29.0 percent to the second and third summers, respectively. Stream-reared hatchery fish gave an intermediate value (17.2 percent to the second summer).

All lots of trout lost weight for some 30 or 40 days when superimposed on a resident population. This loss was more severe and was regained more slowly in pond-reared trout than in transplanted wild trout.

It is held that the low survivability of hatchery fish is due to the absence of natural selection at early stages in the life history.

INTRODUCTION

Since 1950 the Province of Alberta and the University of Alberta have jointly operated a research station at Gorge Creek, Alberta. Up to the present time the main work of this station has been the study of survival of wild and hatchery-reared cutthroat trout in a series of experiments designed to throw light on the cause of low survival in the latter group. The first experiment, on survival of two lots of pond-reared cutthroat trout, has been described by Miller (1952). In the present paper survival experiments on four additional lots of pond-reared trout, one lot of stream-reared hatchery trout, and one lot of transplanted wild trout are described. As further returns from the first two lots have become available since preparation of the 1952 paper, these data also are included. All of the fish were produced from wild parents, not brood stock.

Details concerning Gorge Creek and the experimental procedure may be found in the 1952 paper. Briefly, Gorge Creek is a typical mountain stream of the eastern slopes of the Rockies; it contains native cutthroat trout and no other resident fish. The stream was divided into experi-

mental sections by fish-tight screens made of wood and chicken wire and covered with pound-net twine. The length of the sections ranged from $\frac{1}{2}$ to $\frac{3}{4}$ mile.

The experimental fish were liberated into the sections as early in the year as stream conditions permitted, usually late in June or early July. In 1950 each fish was weighed to the nearest half-ounce and the fork length was recorded. In the succeeding 3 years fish were weighed to the nearest quarter ounce and lengths were not taken. Each fish was marked with a numbered Petersen-type tag. After liberation the fish were captured as often as possible by angling, reweighed, and again liberated. Dead fish washed onto the screens or, less commonly, settled into pools where they were easily seen and removed. Records of mortality and weight changes were obtained for periods of 70 to 100 days during the first summer after planting. Records were also obtained during the second summer after planting and, for some lots of fish, during the third as well. In 1953 the whole experimental area was poisoned with "Fish Tox," and the experiments were brought to a conclusion.

SURVIVAL OF POND-REARED CUTTHROAT TROUT

Lot I.—This lot consisted of 199 3-year-old cutthroat trout that ranged from 12 to 15 inches in fork length and from 3.5 to 11 ounces in weight (average, 6.4 ounces). They were liberated into a section of Gorge Creek on June 16, 1950; the lower screen of their enclosure remained in position until April 28, 1951. The subsequent record of these fish is as follows:

First summer	70 found dead
	84 caught and released
Second summer	5 caught and killed
	2 caught and released
Third and fourth summers	none observed

As 70 fish were found dead during the first summer the maximum survival to fall was 129 trout or 65 percent. There is no reason to believe that unrecorded mortality occurred; therefore the maximum survival of 65 percent is also the probable survival.

Of the seven fish captured during the second summer, five were caught by anglers in the Sheep River, into which Gorge Creek drains. The other two were found in Gorge Creek. Tagged fish in Gorge Creek could be easily seen from the banks; intensive angling and frequent observations enabled the identification of all but a very few of them. It is unlikely that more than the two recorded fish survived in Gorge Creek. The Sheep River below Gorge Creek was intensively fished by anglers. The possibility exists, nevertheless, that more than five of the tagged trout survived after moving into the Sheep River. Miller (in press) has shown that wild cutthroat trout, transferred from one area to another in the same stream, and held there for more than 30 days, remain, after liberation, in the enclosure area. For this reason it is believed that if more of Lot I had survived, the fish would have been found in Gorge Creek.

It is concluded that survival was seven fish or 3.5 percent over the first winter and nil over the second winter.

Lot II.—This lot consisted of 201 2-year-old cutthroat trout from 5 to 8 inches long and weighing 1.5 to 4.0 ounces (average, 2.6 ounces). (The weight range of these fish was incorrectly stated as 1.5 to 3.5 ounces in Miller, 1952.) They were released in a section of Gorge Creek on July 5, 1950. Subsequent records are:

First summer	112 found dead
	16 caught and released

None of the Lot II fish was found in the second, third or fourth summers.

As 112 fish were found dead, the maximum survival to the first fall was 89 fish or 44 percent. In discussion concerning these fish in a previous paper (Miller, 1952) it was pointed out that the ratio of captures of Lot II fish to wild fish (of known number) indicated that only about 30 were in the stream during the late summer. The probable survival has been estimated as 15 percent.

Lot III.—These fish consisted of 102 4-year-old cutthroat trout weighing from 5 to 9 ounces (average, 6.0 ounces). Lot III was liberated in a section of the creek on June 20, 1951. On June 24 a flood washed out the screens. Records were obtained as follows:

First summer	7 found dead
	12 caught
Second summer	5 caught
Third summer	1 poisoned

The fact that these fish were retained in their enclosure for only 4 days makes the returns, particularly for the first summer, not easily comparable to those of Lots I and II. Of the 12 fish caught during the first summer, 6 were taken by anglers in the Sheep River. It is apparent that a number of the trout, probably a large proportion, drifted out of the experimental area. Therefore it is not possible to arrive at a sound figure for probable survival to the first fall. Returns made in the second and third summers are more nearly comparable to those from Lots I and II. Although any fish that survived in the Sheep River were subjected to heavy angling pressure, only one of the second-summer returns came from this source. The records of survivals amount to five fish or 4.9 percent over the first winter, and one fish or approximately 1 percent over the second.

Lot IV.—This lot comprised 63 1-year-old cutthroat trout weighing from less than 1 ounce to 3 ounces (average, 1.3 ounces). They were planted at the same time as Lot III and suffered the same accident, *i.e.*, the screen of their enclosure washed out after 4 days. Records were obtained as follows:

First summer	16 found dead
	1 caught
Second summer	none observed
Third summer	2 caught

For the reasons discussed in connection with Lot III, it is not possible

to arrive at a figure for probable survival to the first fall. The recorded survival over 2 winters was two fish or 3.1 percent.

Lot V.—These fish consisted of 201 3-year-old cutthroat trout that weighed from 1.5 to 6 ounces (average, 2.7 ounces). They were planted on June 11, 1952. Floods washed out the retaining screens on June 12. Records of these fish were obtained as follows:

First summer	26 found dead 15 caught
Second summer	5 caught

The 26 dead fish were found in Gorge Creek; 8 of the 15 fish caught by angling during the first summer came from the Sheep River as did 3 of the second-summer returns. As with Lot III and IV it is not possible to calculate a probable survival to the first fall. The recorded survival over the first winter is five fish or 2.5 percent.

Lot VI.—This lot consisted of 189 3-year-old cutthroat trout that weighed from 2 to 6 ounces (average, 3.1 ounces). They were planted on July 14, 1952, and were retained in their enclosure until September 19, 1952. Records were obtained as follows:

First summer	108 found dead in first week 17 found dead after first week 12 caught and released
Second summer	6 caught or poisoned

The maximum survival to the first fall was 64 fish or 33.8 percent. Since there was no evidence of unrecorded mortality, the probable survival to the first fall is also 33.8 percent. The recorded survival over the first winter was six fish or 3.2 percent.

SURVIVAL OF STREAM-REARED HATCHERY FISH

The low survival of pond-reared fish led to tests of hatchery fish which had been reared under more natural conditions. A small number of such trout was available at Bighill Creek. This stream contains no fish; two large pools in this creek were screened and 600 fingerling cutthroat trout were liberated into them. These trout had spent 1 year in the hatchery and 1 summer in a standard rearing pond. The trout were left in Bighill Creek for 1 summer and 2 winters. They were not fed. At the end of this period 58 were transferred to an enclosure in Gorge Creek. These fish were 3-year-olds, varying from 1 to 9 ounces in weight, but mainly from 1.5 to 3.9 ounces (average, 2.2 ounces). They were released on June 9, 1952, but the screens were washed out in floods on June 12. Subsequent records are as follows:

First summer	4 found dead 3 caught and killed 26 caught and released
Second summer	10 caught or killed by Fish Tox

One fish caught in the second summer had not been recorded in the first summer's catch. Therefore, the observed survival to the end of the first

summer was 27 fish or 46.6 percent. As the screens were lost it is not possible to establish a probable survival for this period. The recorded survival over the first winter was 10 fish or 17.2 percent.

SURVIVAL OF TRANSPLANTED WILD CUTTHROAT TROUT

The six lots of pond-reared cutthroat trout and the stream-reared Big-hill trout were all handled in the same way, *i.e.*, they were weighed and tagged before planting. Many were later recaptured by angling and reweighed. It is possible that the heavy mortalities noted may be in some measure due to this treatment. Accordingly it was decided that a similar experiment should be conducted with wild trout. During the period July 5 to 31, 1951, 152 wild cutthroat trout were caught by angling in the stretches of Gorge Creek above the experimental area. These fish were tagged, weighed, and carried, one or two at a time, in pails of water down to an enclosure and liberated. The average weight of the fish was 2.6 ounces. There were 64 that weighed 2 ounces or less, 70 that weighed from 2.25 to 4 ounces, 17 that weighed from 4.25 to 6 ounces, and 1 that weighed 7.75 ounces. Their ages are not known, but scales were examined from 133 trout that were taken from the same part of the stream and that had a similar weight range (average weight of 2.5 ounces). These fish had the following age distribution:

1 annulus	6 percent	3 annuli	32 percent
2 annuli	57 percent	4 annuli	5 percent

The wild fish used in the experiment were comparable in size and probably in age to the hatchery-reared trout.

The fish were retained in the enclosure for 69 days where they were subjected to the identical conditions that the pond-reared fish had experienced. Twenty-five of these fish killed themselves by trying to force their way through the upper screen of their enclosure. Since this self-destruction constitutes an unnatural mortality, not suffered by the other fish, these 25 have been omitted from consideration, and only the remaining 127 fish have been used as the basis for survival estimates. The record of returns of these fish are as follows:

First summer	3 found dead
	46 caught and released
	4 found dead
Second summer	16 caught and killed
	33 caught and released
	3 found dead
Third summer	30 poisoned
	4 caught and released

In the second summer, 25 of the fish examined bore tag numbers not recorded in the 1951 returns. In the third summer (1953), 8 were found that were not recorded in 1951 or 1952, and 8 more were encountered that had not been recorded in 1952. The recorded survival figures, therefore, become:

To the end of the first summer: $46 + 25 + 8 = 79$ fish or 62 percent

To the second summer: $51 + 8 = 59$ fish or 46 percent

To the third summer: 37 fish or 29 percent.

SUMMARY OF SURVIVAL EXPERIMENTS

The experiments outlined above provide survival figures for six groups of pond-reared cutthroat trout, one group of stream-reared cutthroat trout, and one group of transplanted wild trout. These figures are summarized in Table 1.

The data in Table 1 show differences in survival between pond-reared and wild cutthroat trout. The comparison is particularly valid for Lots I, II, and IV, and the transplanted wild fish, all of which were retained in enclosures during the summer in which they were planted. The estimated survival to the first fall is high for the large hatchery fish (Lot I) and for the wild trout, but low for the two groups of small hatchery fish. The differences became more marked in succeeding years; thus 46 percent of the wild trout survived over the first winter but only 3.5, 3.2 and 0 percent of the comparable hatchery groups. Twenty-nine percent of the wild trout survived over the second winter; none of the two comparable groups of pond fish was found. The wild trout were smaller than two of the hatchery groups and had the same size as the third. Most of the wild trout were of the same age range as the combined groups of hatchery trout. Neither size nor age appears to be the important factor in these observed differences in survival.

The cutthroat trout from Bighill Creek showed overwinter survival intermediate between the wild and the hatchery fish. They are directly comparable to Lot V in that they were the same age (though slightly smaller) both groups were planted the same week of 1952, and the screens of their enclosures washed out almost immediately. During the first summer only 7.5 percent of the Lot V fish were caught whereas 50 percent of the Bighill fish were recaptured. Recorded survivals over the first winter were 2.5 and 17.2 percent, respectively. Inasmuch as both groups were subjected to exactly the same stream conditions and fishing pressure, the difference observed in survival must be due to differences in the viability of the fish.

WEIGHT CHANGES IN PLANTED OR TRANSPLANTED CUTTHROAT TROUT

As was mentioned previously, all trout were weighed individually before planting, and again whenever recaptured. Fish that died and washed against screens were also weighed provided that it was certain death had occurred within a few hours. Fish killed by poisoning were caught with dip nets before they were quite dead and then weighed. Fish found dead in the stream after poisoning or at any other time were not weighed. According to Larimore (1952) certain species of fish gain weight during a short period immediately following death. If such weight changes also occurred in the cutthroat trout after death, they would tend to make the observed losses in weight smaller than the actual losses. Weight checks

TABLE 1.—*Summary of survivals of eight groups of cutthroat trout*
[Figures of survival are percentages of original numbers of fish planted]

Year of planting	Lot	Age	Average weight (ounces)	Number planted	Survival to first fall (estimated)	Survival to second summer (recorded)	Survival to third summer (recorded)
1950	I	3	6.4	199	65.0	3.5	0.0
1950	II	2	2.6	201	15.0	0.0	0.0
1951	III ¹	4	6.0	102	....	4.9	1.0
1951	IV ¹	1	1.3	63	....	....	3.1
1952	V ¹	3	2.7	201	....	....	....
1952	VI	3	3.1	189	....	2.5	....
1951	Wild transplants	1-4	2.6	127	33.8	3.2	....
1952	Bighill Creek ¹	3	2.2	58	62.0	46.0	29.0
					....	17.2	....

¹ These lots were not retained in Gorge Creek by screens, but were free to move shortly after planting

during the first summer were obtained in significant numbers for three groups of fish: Lot I (pond-reared), Bighill Creek, and transplanted wild fish (Table 2).

According to data of Table 2, cutthroat trout superimposed on a resident population lose weight. The loss in weight began immediately and continued for about 30 or 40 days. Thereafter, the fish held their own or gained in average weight. It is in this recovery period that pond-reared and wild trout differed most markedly. Not only did the wild trout lose much less weight on the average but they also regained it much faster.

TABLE 2.—*Weight changes in planted or transplanted trout during the first summer*
[Figures are percentages of original weight lost or gained and numbers in parenthesis are the number of fish used to compute the average]

Days after planting	Lot I, pond-reared	Bighill stream-reared	Transplanted wild trout
0- 10	- 4.5 (15)	- (1)	- 9.5 (9)
11- 20	-13.9 (59)	- (1)	- 1.8 (17)
21- 30	-20.0 (27)	- 3.6 (3)	- 7.3 (8)
31- 40	-14.2 (22)	- 8.8 (10)	0.0 (7)
41- 50	-17.8 (21)	- 2.0 (6)	7.5 (5)
51- 60	-20.8 (8)	3.7 (8)	6.0 (4)
61- 70	-20.8 (14)	12.5 (2)	0.0 (2)
71- 80	-11.8 (15)	- 7.9 (4)	66.5 (1)
81- 90	-10.7 (8)	-12.1 (4)	....
91-100	- 0.3 (2)	8.6 (11)	....

After 50 days wild trout averaged as much or more than their weights at planting; pond-reared trout approached their average weights at planting only after a period of 100 days. Stream-reared hatchery trout were intermediate, but closer to the wild trout; after 50 days 21 weighed more than they had at planting and 8 weighed less.

A small number of first-summer reweighings of fish of Lots II to VI was also available. All of these fish showed losses. Two-year-old, pond-reared trout appeared to have lost more weight and to have recovered much less quickly than the 3-year-olds of Lot I shown in Table 2.

Records of fish weighed in one summer and recaptured and reweighed in a second summer were available for the wild cutthroat trout transplanted in 1951, for the Bighill trout, and for 16 pond-reared fish planted in 1950 to 1952. Twenty-three of the wild transplants and two pond-reared fish were also weighed in a third summer.

Weight changes over one winter may be summarized as follows:

Transplanted wild trout (45 records)	15.1 percent gain
Pond-reared trout (16 records)	2.1 percent gain
Bighill trout (10 records)	9.8 percent loss

Where the number of records is small the possibly aberrant weight changes of one or two fish can distort the general average. The same records may be examined on the basis of numbers of fish showing gain and numbers showing losses, *viz.*:

	76 percent gained
Transplanted wild trout	13 percent lost
	11 percent, no change
	44 percent gained
Pond-reared trout	44 percent lost
	12 percent, no change
	50 percent gained
Bighill trout	40 percent lost
	10 percent, no change

In ability to maintain weight over the winter the wild cutthroat trout were markedly superior. The small number of records for stream-reared hatchery trout and pond-reared trout do not permit a positive conclusion, but little significant difference appeared between them.

Both of the two pond-reared fish reweighed in a third summer had lost weight. Twenty-three transplanted wild trout, weighed in the third summer, showed a net increase of 20 percent over their weight at planting.

SUGGESTED EXPLANATION OF DIFFERENCES IN VIABILITY

Pond-reared cutthroat trout, one generation removed from the wild (eggs from wild parents), were unable to survive in significant numbers in a mountain stream. Wild trout, similarly superimposed on a resident population, showed a survival more than 10 times as great over the first winter, and a still larger comparative survival over the second winter. A marking-and-recovery experiment on Gorge Creek showed a 46.3-percent survival of wild trout over the winter of 1950-51. The transplanted wild trout showed a survival of 46.0 percent over the winter of 1951-1952. It seems reasonable to conclude that the transplanting did not affect the capacity of the fish to survive. This agreement points to a sharp difference between pond-reared and wild trout which cannot be attributed to competition in the stream. The difference must have some connection with the history of the pond-reared fish. The Bighill fish displayed an overwinter survival intermediate between the wild and the pond-reared trout. These fish had spent 1 summer and 2 winters in a natural stream, foraging for themselves. The results show, then, three grades of survival: high, associated with no hatchery background; intermediate, partly hatchery and partly natural background; and low, associated with usual pond-rearing methods.

The weight histories of cutthroat trout superimposed on a resident population brought out similar differences. All lost weight for some 30 to 40 days; but the pond-reared fish lost the most weight and took much longer to recover their losses. An interesting time relationship is indicated in the following account. Data from Gorge Creek (Miller, in press) show that wild trout moved from one part of a stream to another will attempt to return home. If held in the new locality 30 or more days and then released they no longer attempt to return home. Cooper (1953) noted that very few legal-sized hatchery fish planted in streams were caught after the first 40 days. These observations all point to a period

of approximately 40 days that is required by trout to adjust to a new environment. They do not, however, help explain the difference between viability of pond-reared and wild fish; they merely indicate that all superimposed trout are subject to environmental pressures to which they must adjust. Pond-reared fish perform the adjustment with less competence than naturally-reared fish.

Schuck (1948) has listed 10 possible causes of the low survival of hatchery-reared trout. Four of these (stability of water temperatures, domestication, selection of brood stock for good hatchery qualities, and freedom from predation) do not apply to any of the groups tested in this experiment. One of the causes, planting methods, applies to all three groups, and therefore, may be ruled out as a possible contributor to differences in survival. Five of Schuck's causes (four concerned with food and feeding, and one with exercise) apply to the low survival group and to the first 1½ years of the lives of the intermediate survival group. The possibility cannot be ruled out that one, several, or all of these causes account for the differences reported in this paper. It seems to the writer, however, that a simple alternative explanation exists. The three degrees of survival reported in this paper may all be attributed to three degrees of natural selection. The good hatchery operator may rear 30 to 40 percent of his fry to 2- or 3-year-old trout; nature has eliminated 60 to 70 percent. In the Bighill experiment 600 fingerlings yielded 58 3-year-old trout, natural mortality took over 500 or about 85 percent. In nature (Gorge Creek figures) only about 1 percent of the eggs deposited survive to catchable-sized trout; natural mortality is 99 percent. Is it not logical to attribute the observed differences in survival to these differences in degree of natural selection? It is only necessary to assume that those trout in the hatchery which are in excess of the number that would have survived in a stream, succumb to natural forces after they are planted; *i.e.*, the effect of the hatchery is to delay the operation of the rigorous natural selection which prevails in a stream.

If natural selection does operate in the manner suggested above, perhaps some hatchery procedures could be carried out more economically. First it is necessary to define the various uses to which hatchery products are put. If lakes are to be stocked the probable survivals are much higher and, provided the lakes need stocking, present hatchery practice would seem to be economically sound. If streams are stocked, the question arises as to whether the stocking is for immediate recapture (by anglers) or for recapture in later seasons. In the latter case, present hatchery practice is not economic, and it might be better to plant with eyed eggs; ultimate contributions to the creel would likely be as large and the costs would be enormously less. If planting is for recapture the same reason, the situation is not quite so clear. Returns from such plants of legal-sized trout in streams seldom exceed 40 percent and are frequently less. Something like 60 percent of the cost of rearing such fish is wasted. Perhaps it might be valuable to experiment with methods of selection of fry designed to eliminate those which would also be eliminated under natural conditions. For

example, severe competition for food or very swift water, might be used. It would be better economy to kill a large number of fry at the start rather than spend money feeding them, rearing them to legal size, and then turning them loose in a stream for nature to eliminate.

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FLUCTUATIONS IN PRODUCTION AND ABUNDANCE OF COM-
MERCIAL SPECIES IN THE RED LAKES, MINNESOTA,
WITH SPECIAL REFERENCE TO CHANGES
IN THE WALLEYE POPULATION ¹

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ABSTRACT

The Red Lakes in northwestern Minnesota comprise 275,000 acres of water which support a commercial fishery producing up to 1.5 million pounds of fish per year. Walleye, *Stizostedion vitreum vitreum* (Mitchill), and yellow perch, *Perca flavescens* (Mitchill), are the principal species. Statistics for the past 37 years have been analyzed and fluctuations in the abundance of the important species calculated for the 24-year period, 1930-1953. The fishing is carried on exclusively with 3½-inch-mesh (extension measure) gill nets by Chippewa Indians and the catch is marketed through a cooperative fishery enterprise. There have been wide fluctuations in the abundance of principal species but, although fishing effort has increased greatly during the past few years no trends have developed. Changes in walleye abundance have been shown to be independent of changes or levels of fishing effort, and to be determined by strength of individual year classes. Gear competition has no effect on abundance estimates. Strength of year classes is not correlated with size of brood stock, abundance of competing species, or amount of hatchery fish planted. Weather conditions cannot be correlated with observed changes in strength of year classes. Implications for management include provision of adequate prediction of abundance, and annual adjustment of fishing practices to make greatest use of the available stock. Gear limitations should be designed to secure harvest at optimum size of fish and to provide a suitable economic status for the fisherman.

INTRODUCTION

The Red Lakes in northwestern Minnesota have a combined area of 275,000 acres which support a substantial commercial and a minor sport fishery. The commercial fishery is one of the major assets of the Red Lake Band of Chippewa Indians whose members have the exclusive right to commercial exploitation. Major fluctuations in the annual yield to the

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fishermen and questions concerning changes in fishing regulations caused the Office of Indian Affairs to request an investigation of this fishery resource. In 1938 the U. S. Bureau of Fisheries initiated a preliminary survey (Van Oosten and Deason, MS.²). Eleven years later in 1949 a comprehensive investigation was started by the University of Minnesota and the U. S. Fish and Wildlife Service in cooperation with the Office of Indian Affairs. During the first 5 years of this study various problems of immediate concern for management and some additional questions of population dynamics have been examined.

Smith, Krefting, and Butler (1952) demonstrated by tagging studies that the population of walleyes in Upper and Lower Red Lakes could be considered homogeneous for purposes of management. They also found that dispersal after spawning was rapid and that fish moved throughout the lake area. Van Oosten and Deason made preliminary studies of growth rates of commercial species, compiled catch statistics up to 1938, and examined the background of numerous administrative problems.

The present paper includes a compilation of available statistics on yield and fishing intensity and describes fluctuations in abundance of the principal species. An attempt has been made to assess the influence of fishing effort, size of spawning stock, abundance of competing species, planting of hatchery fish, and fluctuation of year-class strength on changes in abundance of walleyes and yellow perch in particular years. The implications of these investigations for management have been considered and certain current management procedures have been evaluated. Although the causes of fluctuation in abundance have not been satisfactorily explained, several possible factors of change have been shown to be of minor significance or of doubtful influence and the lines of further inquiry have been defined.

The Red Lakes consist of two roughly oval basins connected by a channel approximately $\frac{3}{4}$ mile wide. Both lakes are shallow. The upper lake has a maximum depth of 20 feet and a mean depth of approximately 8 feet and the lower lake a maximum depth of 35 feet and a mean of 18 feet. Surrounding soils are bog, sand, and glacial till, but the shores and a large part of the bottom are sand. Waters are derived from seepage and the inflow from a number of tributary streams (Fig. 1). The lake level is maintained by a dam at the outlet into the Red Lake River. This river flows into the Red River of the North which is the most southerly tributary of the Hudson's Bay drainage. The lakes are moderately alkaline (total alkalinity 120 to 135 p.p.m.) and have no thermocline. Circulation of the water by heavy winds causes the water temperature to follow the mean air temperature rather closely. Summer water temperatures in the lower lake range from 62° to 72° F. at all levels.

Of the 38 species of fish in the lakes the following are exploited commercially: walleye; yellow perch; lake whitefish, *Coregonus clupeaformis* (Mitchill); northern pike, *Esox lucius* L.; goldeye, *Amphiodon alosoides*

² Van Oosten, John and Hilary J. Deason. 1941. A preliminary survey of the commercial fisheries and fishery resources of the Red Lakes, Beltrami and Clearwater counties, Minnesota. (Typewritten manuscript).

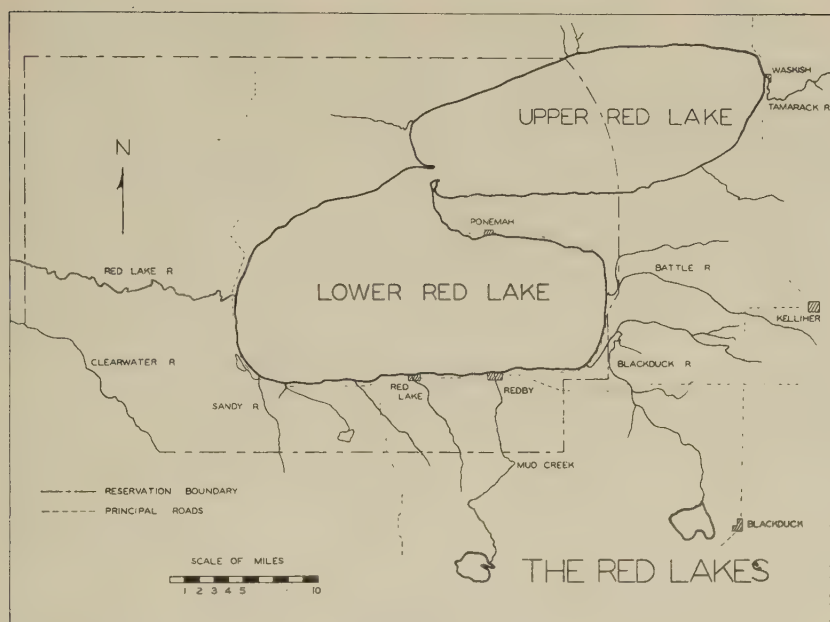


FIGURE 1.—Red Lakes, Minnesota.

(Rafinesque); sheepshead or freshwater drum, *Aplodinotus grunniens* Rafinesque; black bullhead, *Ameiurus melas* (Rafinesque); and white sucker, *Catostomus commersoni* (Lacépède). Other species occasionally occur in the commercial catch but never in quantities large enough to market.

Commercial fishing in Red Lakes was started in 1917 as part of a state-wide war activity to secure a supplementary food supply during the emergency created by World War I. The Minnesota Commissioner of Game and Fish authorized the use of pound nets by state crews and also bought fish from the Indians who employed gill nets and hook and line. In 1919 the Minnesota State Legislature enacted measures which permitted the State Game and Fish Department to engage in commercial fishing. Following this authorization a contract was made between the Commissioner of Indian Affairs and the State of Minnesota governing the sale of fish by the Indians to the state and specifying certain conditions under which fishing could be done. This agreement was made in 1921 and after renewal in 1924 was continued until 1929. Among the provisions of the contract were the establishment of a 650,000-pound quota on game fish (walleye and northern pike) and a 1,500-foot limit per family on 4-inch-mesh (extension measure) gill nets. There is no evidence that a mesh this large was ever used extensively. White men were licensed to fish in the upper lake but their numbers probably never exceeded 18 or 20 fishermen.

In 1929 a court order based on a Minnesota Supreme Court decision restrained the state from further participation in the fishery enterprise. Later in the same year the state legislature authorized the Commissioner of Game and Fish to lease the fishery plant to the United States government and to set up regulations under which the Indians could operate the fishery. The Red Lake Fishery Association was incorporated by the Red Lake Indians under the laws of the State of Minnesota in March 1929 and has conducted the fishery up to the present time. This cooperative enterprise marketed all fish caught by Indians and white fishermen. White fishermen operated only in the upper lake and their average annual contribution to the total catch up to 1937, the last year of their participation, was 4.8 percent (Van Oosten and Deason, MS.—see Footnote 2).

The regulations under which the fishery operated were formulated in 1930 by the Commissioner of Indian Affairs and took cognizance of the regulations laid down by the state for sale of fish off the reservation. Important provisions of these regulations were maintenance of the 650,000-pound annual quota on game fish, establishment of $3\frac{3}{4}$ -inch-mesh gill net, and 1,500-foot maximum limit of gill nets for each fisherman. Because fish were small in 1936, $3\frac{1}{2}$ -inch-mesh nets came into general use. In 1941 use of eight nets or 2,400 feet per fisherman was begun and the quota limitation was ignored in the general war-time speed-up of food production. The Commissioner of Indian Affairs with the approval of the State of Minnesota in 1946 raised the quota to 1 million pounds, legalized $3\frac{1}{2}$ -inch-mesh nets, and officially recognized the use of eight 300-foot nets per fisherman. Following the poor season of 1950 the quota was returned to 650,000 pounds but the other changes were retained.

The Indians fish from skiffs powered with outboard motors on the days specified by the fishery manager who in turn is governed primarily by market conditions. Their nets are set 2 to 5 miles offshore from fishing camps scattered around the entire lake. The nets are lifted and taken to shore before the fish are removed. This procedure frequently results in a poor quality of fish even though they are iced as soon as possible. All fish are picked up by trucks and taken to the fishery building at Redby for grading and shipping.

PRODUCTION OF THE FISHERY

Source of statistics.—Statistics of production and operation of the Red Lakes fishery were maintained from its opening in 1917 until 1928 by the State of Minnesota and recorded in the Biennial Reports of the Game and Fish Commissioner. After the formation of the Red Lake Fishery Association in 1929, all records were kept by its staff. Since 1929 more detailed statistics have been maintained and have been audited annually by the Office of Indian Affairs. The figures for production and fishing effort used in the following analyses have been secured from these two sources. For the period 1914–1937 the data were taken from compilations prepared by the U. S. Fish and Wildlife Service (Van Oosten and Deason,

MS.). Data for the years 1938–1953 were compiled by the authors from the Fishery Association records.

All fish caught in the Red Lakes fishery are marketed through the Fishery Association's plant at Redby. This procedure enables the personnel of the Association to maintain records of production from each fisherman. Since the fishery manager also determines the nights on which fishing is to be done and all fishermen have a standard allotment of gear, a complete history of individual fishing effort is available. Production is recorded in pounds of undressed fish as they are received from the fishermen, except that goldeyes and whitefish are eviscerated and northern pike, white suckers, and bullheads are dressed and headed. All walleyes under approximately 13 inches and whitefish under 3 pounds are graded out as "culls" and have been summarized separately since 1943.

Production figures include all fish bought by the Fishery Association but exclude those which had no current market value. In some years large quantities of suckers were taken but, because they could not be sold, were not listed in returns. A small percentage of undersized perch (less than $8\frac{1}{2}$ inches) is caught by the commercial nets, but is discarded before weights are taken.

The fishery records do not include fish caught illegally and by anglers in the upper lake. It is estimated that these catches never exceed 10 percent of the commercial catch and are usually much less. Indians may fish the year around for home consumption of fish, but this removal is negligible in comparison to the regular catch.

Method of calculating fishing effort and abundance.—Since gill nets have been used exclusively during the greater part of the fishing history in these lakes, a standard set of 1,500 feet of $3\frac{1}{2}$ -inch-mesh gill net fished for 1 night was selected as a unit of fishing effort. The fishing is organized so that nets are rarely in the water more than 18 and usually less than 12 hours. Sets normally are made between 4:00 and 5:00 p.m. and nets are lifted between 4:00 and 6:00 a.m. the following morning. When fishing is done on consecutive nights, the nets are taken from the water and dried before they are reset. The mesh size was changed from $3\frac{3}{4}$ inches to $3\frac{1}{2}$ inches in 1936 but no correction for this possible increase in efficiency has been attempted.

Total production of a fishery is sometimes used as an index to abundance of a species. Hile, Eschmeyer, and Lunger (1951b) hold that under certain conditions (over limited periods of years and with no major changes in fishing methods or regulations) production statistics indicated but did not measure changes in abundance of some Great Lakes stocks. They urged caution in this use of production records. In Red Lakes a quota on production and wide fluctuation of effort make this system unusable for years when records of effort were not kept. All estimates of abundance, therefore, have been calculated on the basis of the average pounds of fish caught in a single five-net lift as determined from the total number of lifts and the total production during any season. Since the size of the catch does not seem to vary with the number of hours as long as both night and morning

periods of fish movement are included, the overnight set as a unit of effort gives the most dependable results.

To facilitate the study of production and abundance, the years during which the fishery has been operated were divided into two periods, 1917–1929 and 1930–1953. These major periods were selected because the statistics taken prior to 1930 are not adequate to permit detailed analysis. The second was further divided into a “base period” from 1930 to 1940 when five nets per fisherman were used, and a late period from 1941 to 1953 when eight nets per fisherman were employed. In addition to analysis of data on the basis of pounds and number of units, values for the entire 24 years, 1930–1953, have also been expressed as percentages of the averages for the 11-year base period, 1930–1940. To permit operation of a whitefish hatching program, a fall fishing season was carried on until 1947 when hatchery operations were discontinued. Since 5-inch-mesh (extension measure) nets were used during these seasons, annual estimates of abundance have been derived for summer fishing only.

Total production.—Commercial production of fish from Upper and Lower Red Lakes which started in 1917 has fluctuated widely in response to economic trends and changes in abundance of fish and in fishing intensity. The total yield of all species has varied from a low of 322,684 pounds in 1920 to a high of 1,533,958 pounds in 1947 (Tables 1 and 2). Throughout the history of the fishery walleyes have been predominant in the commercial catch. The yellow perch, which was a minor element of the catch in the early years, has built up steadily to a position second to the walleye. Whitefish was an important contributor to total production in early years but has gradually declined until it is significant only in occasional years.

Goldeyes which apparently were abundant during the early years of exploitation were not recorded separately until 1927. There is considerable evidence that prior to 1930 many goldeyes were caught but were not marketed. After 1936 production gradually declined until, at present, this species forms a negligible part of the total annual catch. Northern pike make a minor contribution to the annual catch but are important because they are combined with walleyes to determine the fulfillment of the annual quota. Bullheads, sheepshead, and white suckers are also taken in small numbers. Since 1941 walleyes and perch have made up an average of 85 percent of the total catch and in some years have contributed as much as 94 percent of total commercial production.

Production in 1917–1929.—During 1917–1929 fishing methods and the reporting of statistics were not uniform. Therefore, the published figures are not complete enough for discriminating comparison with those for 1930–1953. The first years of the early period were a time of experimentation with methods and development of markets. Verbal reports from older fishermen indicate that large quantities of white suckers, goldeyes, and sheepshead were caught and destroyed because they could not be marketed, or were reported only as rough fish (Table 1). Economic conditions and frequent changes of management and policy may have influenced the yield more than actual abundance of desirable species.

TABLE 1.—*Production (pounds) of the commercial fishery of the Red Lakes, 1917-18 to 1929*

Year	All species ¹	Walleye	Yellow perch	Whitefish	Northern pike	Sheepshead	Goldeye	White sucker	Bullhead
1917-18.....	825,446	356,023	756	190,878	29,998	69,119	67,552	78,289	1,948
1918.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1919.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1920.....	322,684	186,751	.....	39,463	.....	.....	.....	.....	.....
1921.....	645,357	500,275	12,108	64,235	.....	.....	.....	.....	.....
1922.....	838,162	744,376	16,994	18,444	.....	.....	.....	.....	.....
1923.....	715,952	523,297	30,875	114,975	26,611	.....	.....	.....	.....
1924.....	959,614	743,092	19,046	82,765	60,869	.....	.....	.....	.....
1925.....	931,750	.....	.....	.....	.....	.....	.....	.....	.....
1926.....	855,055	610,024	60,379	9,726	29,375	.....	.....	.....	.....
1927.....	792,452	547,325	109,267	52,564	15,645	14,133	52,077	847	591
1928.....	720,455	503,093	69,113	85,574	23,452	7,696	25,151	5,602	614
1929.....	1,086,473	694,879	137,469	134,850	61,067	11,579	19,542	25,026	488
Total.....	9,232,044	5,409,135	456,007	793,474	247,017	102,527	164,322	109,764	3,641
Annual average ²	769,377	540,913	50,667	79,347	35,288	25,631	41,080	27,441	910

¹ Totals include rough fish not separately listed

² Averages are based on number of years reported; not on total years in period

Total reported annual production for 1917–1929 attained a maximum of 1,086,473 pounds in 1929; the annual average for the 12 years was 769,377 pounds. Walleyes, the predominant fish in the catch, reached a high of 744,376 pounds in 1922 and averaged 540,913 pounds for the period. Yellow perch did not appear in the fishery until 1921 when 12,108 pounds were reported. As the perch market developed, the reported catch gradually increased to 137,469 pounds in 1929. Throughout the entire early period whitefish made up an important part of total production with a maximum yield of 190,878 pounds in the 1917–1918 fiscal year and an average production of 79,347 pounds.

Some lake sturgeon, *Acipenser fulvescens* Rafinesque, were taken during the early years of the fishery, but the last commercial report was in 1921. Small amounts of caviar were produced in 1917 and 1918 but none thereafter. The most recent observation of a large sturgeon was made in 1941, when a 140-pound specimen was taken at Waskish in traps set to take spawning walleye for the hatchery operation. Small quantities of "white carp" (presumably *Carpiodes* sp.) were reported in 1917–1918 and again in 1927–1930.

Production in 1930–1940.—The period 1930–1940 was marked by severe economic pressures and by unusual climatic and water conditions that may have affected production. Prices for fish were poor and the lake reached a very low water stage. Total production was only 721,419 pounds in 1935, but the period ended with a total take of 1,185,647 pounds in 1940, the maximum production for a single year up to that date. The average annual production of 921,306 pounds exceeded the average of the previous period by approximately 150,000 pounds. Annual fluctuations in total production were relatively not as great as changes in yield of individual species which tended to compensate each other; in 1936, for example, goldeyes bolstered the catch in a disastrous walleye year (Table 2, Fig. 2).

In the 11 years, 1930–1940, the production of walleyes averaged 567,305 pounds but in 4 different years the total quota was exceeded by walleyes alone. From the high production of 746,215 pounds in 1931 the catch declined to 308,185 pounds in 1936, an all-time low for the fisheries with the exception of the take in 1920. Production recovered quickly and in 1940 reached 799,753 pounds, the maximum up to that time.

Yellow perch became a major factor during this period, with an average annual production of 164,711 pounds, or more than three times the average of the previous 13 years. Only 76,963 pounds of perch were caught in 1930 but the annual harvest had a general upward trend until a peak of 237,561 pounds was attained in 1937.

The goldeye harvest fluctuated from its lowest point, 362 pounds in 1933, to an all-time high of 247,383 pounds in 1936. This spectacular rise was followed by a decline to 148,191 pounds in 1940. The annual average of 79,091 pounds substantially exceeded the average of the preceding period, but incomplete reporting during much of 1917–1929 does not permit accurate comparison. Whitefish made major contributions to the total

TABLE 2.—*Production (pounds) of the commercial fishery of the Red Lakes, 1930-1953*

Year	All species	Walleye	Walleye (cull)	Yellow perch	Whitefish	Whitefish (cull)	Northern pike	Sheepshead	Goldeye	White sucker	Bullhead
1930.....	746,862	453,431	.....	76,963	117,280	.....	42,049	17,601	26,393	11,612	775
1931.....	1,061,837	746,215	.....	96,109	142,581	.....	32,364	22,741	2,635	8,166	1,046
1932.....	983,546	651,699	.....	153,542	132,716	.....	28,177	14,524	1,890	.....	686
1933.....	783,373	542,056	.....	183,063	28,283	.....	13,232	14,880	362	761	736
1934.....	866,953	502,832	.....	170,138	126,227	.....	25,750	17,719	22,346	1,147	794
1935.....	721,419	359,206	.....	167,842	47,826	.....	9,222	25,937	101,770	8,906	710
1936.....	757,217	308,185	.....	116,497	26,131	.....	13,781	42,733	247,383	2,104	403
1937.....	1,018,225	614,220	.....	237,561	38,874	.....	12,075	18,624	96,715	.....	156
1938.....	1,061,786	683,225	.....	230,703	14,732	.....	19,729	14,959	98,369	.....	59
1939.....	947,507	579,536	.....	199,924	1,927	.....	23,909	15,198	123,912	2,735	366
1940.....	1,185,647	799,753	.....	179,484	3,302	.....	29,547	18,882	148,191	3,468	3,020
1941.....	1,218,666	929,528	.....	98,654	1,382	35	34,137	14,501	135,822	1,288	3,308
1942.....	1,285,108	940,887	.....	165,127	4,629	.....	42,768	18,004	111,354	.....	2,339
1943.....	1,311,975	784,865	38,962	203,780	17,819	1,290	27,903	22,434	117,425	95,067	2,430
1944.....	1,469,917	953,596	15,991	346,695	12,072	1,499	43,668	11,956	56,725	26,534	1,181
1945.....	1,451,320	856,884	15,810	322,705	7,726	2,362	97,296	11,047	108,126	27,905	1,594
1946.....	1,478,411	892,313	19,151	336,724	18,529	14,667	116,379	11,466	47,694	19,788	1,700
1947.....	1,533,958	941,440	35,988	335,962	5,127	41,390	76,551	16,035	51,783	28,000	1,682
1948.....	1,363,398	921,614	6,898	251,228	867	78,098	51,246	15,343	15,361	20,619	2,124
1949.....	1,060,576	635,714	24,410	185,496	10,632	64,332	77,236	13,259	18,108	27,991	3,398
1950.....	652,373	364,341	19,106	79,579	17,826	47,276	47,248	9,880	49,007	14,360	3,750
1951.....	757,535	544,956	11,273	111,907	15,819	4,682	29,875	20,492	10,316	.....	8,215
1952.....	1,116,926	641,397	12,813	393,387	2,908	3,186	24,389	13,002	3,878	19,433	2,533
1953.....	1,054,450	517,238	20,262	453,686	6,961	21,854	19,865	9,366	4,260	.....	958
Average 1930-1940.....	921,306	567,305	.....	164,711	61,807	.....	22,712	20,345	79,091	3,536	796
Average 1941-1953.....	1,211,893	763,444	20,060	252,686	9,407	23,389	52,966	14,368	56,143	28,099	2,708
Average 1930-1953.....	1,078,707	682,741 ¹	.....	212,365	45,119 ¹	.....	39,100	17,108	66,659	17,771	1,831

¹ Average of culls and regulars combined

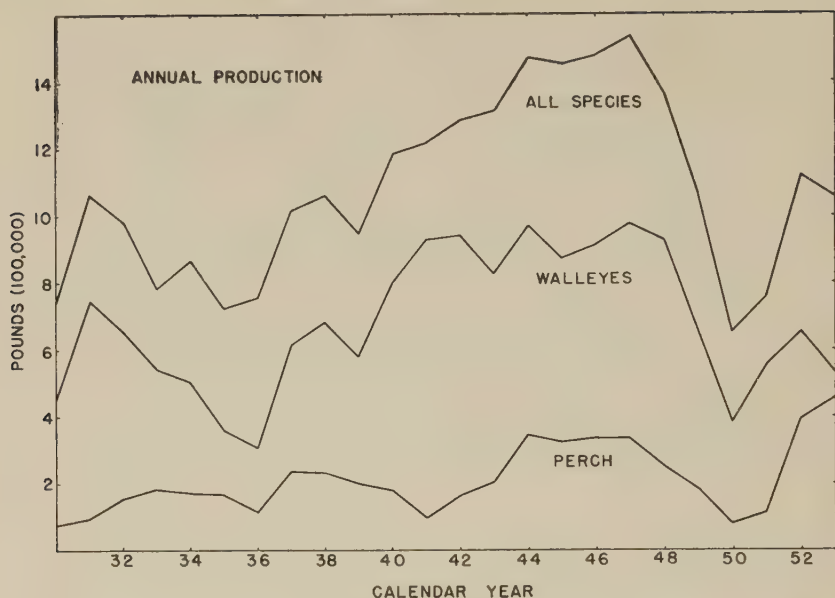


FIGURE 2.—Annual production of walleyes, yellow perch, and all species combined from the Red Lakes commercial fishery, 1930–1953.

catch, with an average annual yield of 61,807 pounds. They reached an all-time peak of 142,581 pounds in 1931 but rapidly declined to a minimum of 1,927 pounds in 1939. Production during the latter years was consistently poorer than in 1917–1929.

Production in 1941–1953.—The 1941–1953 period was ushered in by a substantial increase in fishing effort, raising of walleye-northern pike quota to 1,000,000 pounds, and an unlimited demand for fishery products brought on by World War II. The greatest production in the history of the fishery was attained in 1947, when 1,533,958 pounds were harvested (Table 2). The take in this year was 166.5 percent of the average production for 1930–1940. In 1950 the total production of 652,373 pounds was the lowest since 1921 and only 70.8 percent of the average for the 1930–1940 base period. The average annual production for the 13 years was 1,211,893 pounds, an increase of 31.5 percent over that of 1930–1940. In 1950 a quota of 650,000 pounds of walleye and northern pike was again imposed and the production reduced to the levels comparable with those of the previous period.

The largest production of walleyes ever attained was made in 1947 when 977,428 pounds were taken. On the other hand, only 383,447 pounds, the lowest walleye production since 1936, were harvested in 1950. In spite of this low an annual average of 780,418 pounds, 35.5 percent higher than that of the previous period, was maintained.

Production of yellow perch reached an all-time high of 453,686 pounds in 1953 and maintained an annual average of 252,686 pounds. This average was approximately 53 percent higher than that of 1930–1940 and about five times greater than that of 1917–1929. Production of goldeyes averaged 56,143 pounds, but a continual decline throughout the period culminated in low yields of 3,878 and 4,240 pounds in 1952 and 1953. Whitefish reached the lowest point in their history in 1941 when 1,417 pounds were taken. The greatest yield of the period was 78,965 pounds in 1948, and the average was 30,997 pounds or slightly less than half that of the previous period.

During the greater part of 1941–1953 separate records were kept of the production of cull walleyes and whitefish. Cull walleyes averaged 20,060 pounds and reached a maximum of 38,962 pounds in 1943. Cull whitefish averaged 23,389 pounds and attained a high of 78,098 pounds in 1948. In 1950 the entire fishery suffered a major collapse as a result of low production of walleyes and yellow perch. Hardship on fishermen was lessened by slightly improved goldeye and substantial whitefish production in this year.

Fluctuations in walleye production.—Fluctuations in walleye production have been governed more by abundance and economic trends than by the annual quota on game fish. Changes in yield of northern pike, which are combined with walleye in the quota, have not influenced production of the latter species to any great extent since northern pike only occasionally exceed 10 percent of the combined catch and usually contribute less than 5 percent.

From the beginning of operations in 1917 until 1940, annual walleye production fluctuated about a mean of approximately 550,000 pounds, although there were extreme low points in 1920, 1935, and 1936. In 1941, production rose sharply and until 1948 averaged approximately 60 percent higher than in 1930–1940. After 1948 a sharp decline culminated in the extreme low of 1950. Recovery of production to a point above the average of the base period was again attained in 1952. It will be noted from Tables 2 and 3 that the increase during the later years was accompanied by a substantial rise in the average fishing effort.

Fluctuations in yellow-perch production.—Production of yellow perch has been influenced primarily by abundance and by the length of the season which in turn was dictated by the extent of the walleye production. Production of perch first reached a high level in 1927 and thereafter the perch maintained its importance in the fishery in spite of considerable annual variation. The longest period of high sustained yield was 1944–1948 when the annual return was never less than 251,000 pounds and the annual average was 93 percent above that of the base period. In 1953 an all-time high was attained which was 175 percent greater than the 1930–1940 average and 15 percent greater than the previous high of 1952. No trend is apparent and the extremes appear to reflect normal changes in abundance.

Fluctuations in whitefish production.—Production of whitefish has

varied rather widely from year to year but the trend has been generally downward throughout the history of the fishery. The annual averages were 79,347 in 1917-1929, 61,807 in 1930-1940, and 30,997 pounds in 1941-1952. Production was low in 1926, 1939-1942, and 1952. Major peaks occurred in 1923, 1929-1932, 1934, and 1948-1949. Although the trend in average production appears to be downward, it is possible that during recent years whitefish have been fluctuating about a more or less stable mean lower than the average during earlier years. As will be pointed out later, analysis of abundance supports this view.

Fluctuations in production of other species.—Of the minor commercial species the goldeye has played the most important part in the fishery. Its production was marked by high yields in 1935-1936 and 1939-1945. A complete failure occurred in 1933 but the species quickly recovered. As the result of a more or less steady decline which started in 1946, the fish were an insignificant part of the total catch by 1953.

Since production statistics for northern pike are recorded in terms of dressed fish, comparison with actual poundages of other species is difficult. However, fluctuation in yield can be compared. The northern pike was not regularly reported until 1926 although prior to that time it was readily available as an occasional annual report shows. For the years 1930-1935 the production of pike averaged 39,100 pounds or approximately 6 percent of the average walleye production. In the year of greatest pike production (1946) the take amounted to approximately 13 percent of the walleye catch. The years 1945 and 1946 were substantially above average and the years 1933-1937 were much less than the average. With these exceptions, production has fluctuated without trend during the history of the fishery.

Sheepshead or freshwater drum have been marketed since 1927, but have never constituted an important segment of the total catch. Since these fish are only slightly vulnerable to the gear because the gill-net mesh is too small to take them readily, any analysis of trends appears to be impractical. The take of white sucker has varied greatly, but since no record of catch was made in 15 of the 37 years of the fishery, analysis of trends appears to be impossible. No consistently high production was reported until the war years when catches ranged from approximately 14,000 to 95,000 pounds. Bullheads have been taken incidentally to other fishing and trends in production appear to have no significance.

FISHING EFFORT

Since it has been demonstrated that the walleyes of the two lakes are from the same population (Smith, Krefting, and Butler, 1952) and it is known that fishermen from the Ponemah-Point area fish in either lake, depending on weather conditions, the fishing effort in the two lakes has been combined. This combination is further desirable because only a small percentage of total effort is expended in the upper lake. Fishing effort prior to 1930 has not been considered since accurate statistics are unavailable, but the intensity was probably not as great as it was thereafter.

With the exception of fishing for personal use and some illegal operation,

the commercial season is limited to a 90-day period between the middle of June and the middle of September. Before 1947 there was a short fall season in late October and November.

The total number of nights fished in the summer season from 1930 to 1953 varied from 104 in 1936 to 23 in 1953 and averaged 49. After the termination of fall fishing, the average number of nights fished in the summer season declined to 39 but the average number of nets in the lake during the last 6 years increased substantially (Table 3, Fig. 3). When the

TABLE 3.—*Total lifts (five-net units) per year, average number of days in summer season, average number fishermen per summer night, and percentage of fishing done in summer and fall in the Red Lakes, 1930 to 1953*
[The fall fishery was discontinued after 1947]

Year	Summer nights fished	Average fishermen per night	Fishing effort		
			Total lifts	Percentage of total	
				Summer	Winter
1930	29	...	8,447	77.6	22.4
1931	45	...	8,609	67.3	32.7
1932	46	...	7,780	49.6	50.4
1933	61	...	5,876	92.2	7.8
1934	70	...	8,577	77.8	22.2
1935	87	...	8,547	82.9	17.1
1936	104	...	8,414	93.2	6.8
1937	40	...	6,565	78.8	21.2
1938	32	86	6,163	79.7	20.3
1939	37	110	6,158	91.9	8.1
1940	43	120	7,265	91.0	9.0
1941	34	117	9,292	87.0	13.0
1942	41	172	13,099	98.7	1.3
1943	86	91	15,947	92.9	7.1
1944	44	92	9,842	85.9	14.1
1945	50	108	11,899	88.8	11.2
1946	39	130	12,948	85.7	14.3
1947	44	157	13,672	90.6	9.4
1948	33	190	10,083	100.0	....
1949	34	182	9,905	100.0	....
1950	53	150	12,768	100.0	....
1951	59	105	12,449	100.0	....
1952	33	148	7,856	100.0	....
1953	23	187	6,883	100.0	....
Average, 1930-1953	49.0	...	9,960	....	....
Average, 1930-1947	51	...	....	83.8	16.2
Average, 1930-1940	54	...	7,491	80.2	19.8
Average, 1941-1953	44	141	11,280	....	....

number of fishermen is large the length of the season is usually shorter than when fishermen are few. Since 1938 the average number of fishermen per summer night has varied from 86 in 1938 to 190 in 1948. On particular nights as many as 235 fishermen may be operating nets but during a storm there may be only 40. Fishermen are usually most numerous during periods of high seasonal availability and in years when fish are easy to catch. Whereas in years of low abundance there are fewer fishermen but their effort is more consistent.

In order to permit comparison of various years all records of effort have

been corrected to five-net lifts. For years when fall fishing was carried on, the number of lifts in the late season has been corrected on the same basis as the summer lifts for the same years. Production of walleyes during fall fishing suggests that a number of 3½-inch-mesh nets were used in addition to the regular whitefish nets.

Because the number of nets allowed by regulation is not always used and exact reports are unobtainable, yields from fishermen whose methods were carefully checked were compared with the average yield of all fishermen in various years. This comparison has shown that the average effort per fisherman agrees with the standard units reported. In a few years the actual effort per man was somewhat above the legal limit but appropriate corrections have been made for these cases.

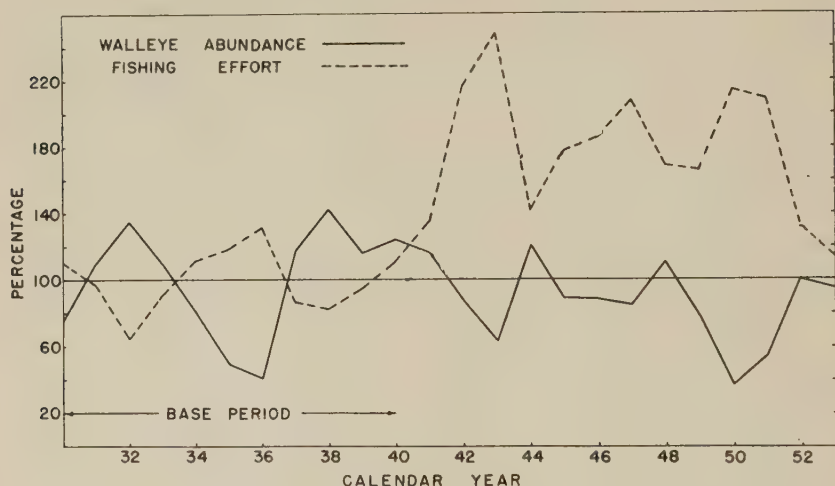


FIGURE 3.—Abundance of walleyes and total summer fishing effort in the Red Lakes, 1930 to 1953, expressed as percentage of the 1930–1940 average.

The average annual fishing effort (Table 3) increased greatly during the 13 years following 1941. In the base period (1930–1940) the average number of lifts was 7,491 per season and from 1941 to 1953 it was 11,280—a gain of approximately 50.5 percent. The maximum effort was exerted in 1943 when 15,947 lifts were made and the minimum occurred in 1933 (5,876 lifts).

Since the fall fishery has special characteristics (conducted with 5-inch nets and discontinued in 1947) summer effort provides a better basis for comparisons during 1930–1953. The average number of summer lifts was 5,965 during the base period 1930–1940 and 10,636 in 1941–1953—a rise of 78 percent (Table 4). Summer effort in terms of percentage of base-period average varied from 64.7 percent in 1932 to 248.4 percent in 1943 (Table 5, Fig. 3). At no time after 1939 did the annual effort fall to the

TABLE 4.—Total summer lifts (five-net units) and average catch (pounds) per summer lift of commercial species in the Red Lakes for the 24-year period, 1930-1953

Year	Total summer lifts	All species	Walleye	Yellow perch	Lake whitefish	Northern pike	Sheepshead	Goldeye	White sucker	Bullhead
1930.....	6,586	85.2	61.0	11.3	2.6	2.7	2.6	4.0	1.0	0.1
1931.....	5,794	113.0	90.0	13.4	2.1	2.9	3.4	0.3	0.6	0.2
1932.....	3,860	158.0	110.9	33.4	6.2	3.4	3.4	0.5	0.0	0.2
1933.....	5,417	129.8	90.0	32.8	2.6	1.3	2.7	0.1	0.1	0.1
1934.....	6,672	100.0	66.1	23.2	2.6	2.2	2.5	3.0	0.2	0.1
1935.....	7,087	82.3	40.8	21.0	3.0	0.7	3.5	13.0	0.1	0.1
1936.....	7,842	88.2	33.8	14.5	1.8	1.2	5.4	31.4	0.1	0.1
1937.....	5,172	163.2	96.3	43.5	0.1	1.1	3.6	18.6	.. ²	.. ¹
1938.....	4,910	182.6	117.0	41.4	.. ¹	1.5	2.8	19.8	.. ²	.. ¹
1939.....	5,657	157.1	95.5	33.8	.. ¹	3.3	2.7	21.8	.. ²	0.1
1940.....	6,614	154.6	102.0	24.0	0.1	3.1	2.8	22.2	.. ²	0.4
1941.....	8,086	129.1	95.6	11.2	.. ¹	3.2	1.8	16.7	.. ²	0.6
1942.....	12,934	98.6	72.2	12.7	0.3	3.2	1.9	8.6	.. ²	0.3
1943.....	14,816	82.8	52.4	13.0	0.2	1.5	1.5	7.8	6.2	0.2
1944.....	8,454	150.4	99.4	37.1	0.2	2.8	1.4	6.6	2.8	0.1
1945.....	10,596	122.3	72.9	28.2	0.3	7.1	1.3	10.1	2.6	0.1
1946.....	11,092	114.3	72.8	26.9	1.1	6.7	1.0	4.3	1.4	0.2
1947.....	12,393	110.3	69.9	25.4	2.9	4.5	1.2	4.2	2.6	0.1
1948.....	10,083	133.0	90.9	24.8	7.8	5.5	1.5	1.5	2.0	0.2
1949.....	9,905	106.8	64.1	18.7	7.6	7.8	1.3	1.8	2.8	0.3
1950.....	12,768	51.1	30.3	5.6	5.1	3.7	0.8	3.8	1.1	0.3
1951.....	12,449	60.9	44.7	9.0	1.6	2.4	1.6	0.8	.. ²	0.6
1952.....	7,856	142.2	83.3	50.7	0.8	3.1	1.7	0.5	.. ²	0.3
1953.....	6,883	153.2	78.1	65.9	4.2	2.9	1.4	0.6	.. ²	0.1
Average 1930-1940.....	5,965	128.5	82.1	26.5	1.9	2.1	3.2	12.2	0.4	0.2
Average, 1941-1953.....	10,636	111.8	71.3	25.3	2.5	4.2	1.4	5.2	2.7	0.3
Average, 1930-1953.....	8,495	119.5	76.3	25.9	2.2	3.2	2.2	8.4	1.7	0.2

¹ Less than 0.05 pound² No suckers bought in fishery

TABLE 5.—Fishing effort (total annual fow-net lifts) and abundance of commercial species expressed as percentage of the 1930-1940 average

Year	Total effort	All species	Walleye	Yellow perch	Whitefish	Northern pike	Sheepshead	Goldeye
1930	110	66	74	43	135	127	81	33
1931	97	88	110	50	109	136	106	2
1932	65	123	135	125	323	160	106	4
1933	91	101	110	123	135	61	84	1
1934	112	78	81	87	135	103	78	25
1935	119	64	50	79	156	33	109	106
1936	132	69	41	55	94	56	168	257
1937	87	127	117	164	5	52	112	152
1938	82	142	142	156	...	70	87	162
1939	95	122	116	127	...	155	84	178
1940	111	120	124	90	5	146	87	181
1941	136	100	116	42	...	150	55	136
1942	217	77	88	48	16	150	59	70
1943	248	64	64	49	11	71	47	64
1944	142	117	121	139	11	133	43	54
1945	178	95	89	106	16	331	40	83
1946	186	89	89	101	58	315	31	35
1947	208	86	85	96	153	211	37	34
1948	169	104	111	93	411	258	47	12
1949	166	83	78	70	400	366	40	15
1950	214	40	37	21	268	174	25	31
1951	209	47	54	34	86	113	50	7
1952	132	111	101	191	41	146	53	4
1953	115	119	95	248	220	136	42	5

: Less than 0.05 pound

level of the base-period average and only in 1953 did it fall below the level of the highest year in the base period.

Fall fishing contributed a substantial part of the year's effort from 1930 to 1938. In 1932 it formed 50.4 percent of the total. After 1938 it did not exceed 14.3 percent and in only 3 years rose above 11.2 percent. In 1942 it contributed 1.3 percent. During the 18 years between 1930 and 1947 fall fishing formed 16.2 percent of the annual average and from 1941 to 1947 it made up an average of 10 percent of the annual effort.

Because there has been a quota on walleyes, the annual effort has fluctuated widely according to the abundance of that species. In a number of years, however, economic considerations and markets had more influence than quota and abundance.

Fall fishing.—A fall fishing season was carried on from 1924 to 1947 for the primary purpose of collecting whitefish eggs to supply the hatchery at Redby. In addition to whitefish, large quantities of other species were taken and marketed through the cooperative fishery. Fall fishing ended with the discontinuance of whitefish propagation in 1947. During the early years of the fall fishing, a large proportion of the summer fishermen participated in this activity, but in the later years their numbers decreased substantially.

The relative importance of the fall season from the commercial standpoint dwindled considerably after the rise in summer fishing effort that started with the increase of nets in 1941 (Table 5). The combined catch of all species during the late season has varied from 38.4 percent of the total annual catch in 1931 to 0.8 percent in 1942 (Table 6). Over the entire period, fall fishing has made an average contribution of 15.9 percent to the annual total.

Since whitefish were the primary objective of the fall fishery, a large part of the annual production of that species was taken during the late season. This production varied from a high of 99.7 percent of the total annual catch in 1938 to a low of 22.3 percent in 1947; the annual average of the percentages for the 18-year period was 72.9 percent. When fall fishing ceased, a sharp decline in total whitefish production was anticipated, but the average harvest for the first 3 years in which all fishing was carried on in summer was the highest since 1934 (Table 1). The bulk of the fish taken after 1947 were in the "cull" class (less than 3 pounds). It therefore appears that the regular summer fishery will harvest the crop but at a smaller average size.

Substantial numbers of walleyes were produced during the fall season with a high of 34.4 percent of the annual harvest in 1932 and a low of 0.7 percent in 1942. The average contribution of the fall production of walleyes to the total catch was 14.4 percent. Annual production of walleyes since 1947 has declined but the smaller take is a reflection of lower abundance rather than a decrease in length of season (Table 4).

The fall catch of northern pike was an important part of the total annual take. The percentage varied from a high of 62.0 in 1938 to a low of 2.7 in 1943, and averaged 37.7. After 1947, however, there was no decline in

production traceable to the discontinuance of a late season. All other commercial species were taken in small quantities during the fall season in spite of the fact that some quantities of regular 3½-inch-mesh commercial gear were probably employed at all times.

The closure of the late season appeared to have little effect on the total annual production since fluctuations in recent years have been similar to those prior to 1947. The actual benefit of the late season was limited largely to the production of a greater proportion of large whitefish and to the provision of an additional period of occupation for some fishermen.

TABLE 6.—Percentage of the total annual catch and of the annual catch of the principal species in the Red Lakes fishery captured in the fall fishing season 1930-1947

Year	All species	Walleye	Yellow perch	White-fish	Northern pike	Sheeps-head	Goldeye	White sucker	Bullhead
1930.....	24.8	11.4	3.1	85.4	58.2	3.1	1.2	46.3	0.5
1931.....	38.4	30.1	19.0	91.6	48.3	14.0	32.6	55.1	1.2
1932.....	38.0	34.3	15.9	82.0	53.6	10.0	2.8	0.0	9.6
1933.....	10.3	10.1	2.8	49.8	46.8	1.5	8.6	11.8	6.8
1934.....	23.1	12.3	8.9	86.1	42.3	6.8	10.4	.....	11.3
1935.....	19.1	19.4	11.1	54.9	43.4	4.6	9.6	91.1	7.9
1936.....	8.7	13.9	2.7	46.0	34.3	0.7	0.6	53.5	0.7
1937.....	17.1	18.9	5.3	98.5	53.1	1.3	0.4	0.0	0.0
1938.....	15.5	15.8	12.0	99.7	62.0	6.8	1.0	0.0	5.1
1939.....	6.2	6.9	4.2	95.6	21.2	0.4	0.5	100.0	0.1
1940.....	13.7	15.7	11.5	87.2	30.3	0.8	0.9	100.0	10.9
1941.....	14.3	16.7	7.6	89.5	23.5	1.0	0.8	100.0	4.7
1942.....	0.8	0.7	0.3	24.3	2.7	0.1	0.1	0.0	0.0
1943.....	6.4	5.7	5.3	83.1	18.9	0.5	1.0	2.5	0.2
1944.....	13.5	13.3	9.6	86.3	55.1	2.9	1.5	10.0	3.3
1945.....	10.7	11.5	7.3	68.1	23.2	0.6	0.7	3.3	1.4
1946.....	14.2	11.4	11.5	61.7	36.0	4.0	1.6	21.6	2.1
1947.....	10.9	11.4	6.2	22.3	27.1	1.6	0.6	10.3	1.2
Average.....	15.9	14.4	8.01	72.9	37.7	3.37	4.16	28.64	3.72

FLUCTUATIONS IN ABUNDANCE

Walleye.—Prior to 1930, walleye production gave little indication of periods of very high or low abundance, although there is some evidence that fish were below average availability in 1921 and 1928. In the 24-year period after 1930, when reliable estimates of abundance could be made, the catch of walleyes per five-net lift ranged from a minimum of 30.3 pounds in 1950 to a maximum of 117.0 pounds in 1938 and averaged 76.3 pounds. In terms of percentage of the base-period average (1930-1940) the availability ranged from 37 to 142 (Table 5, Fig. 3). Abundance was low in 5 years (1935, 1936, 1943, 1950, and 1951) and extremely high in 2 (1932 and 1938). Moderate highs occurred in 1937, 1939, 1940, 1944, and 1948. Other years were near the mean or below it.

In the 13 years between 1941 and 1953 the average level of abundance was 13 percent below the average level in the 11-year base period. This decrease is coincident with the great increase in the level of fishing effort. The data offer some suggestions of a cycle with 7 years between minima. It is not believed that these fluctuations represent cycles in a true sense,

since the corresponding highs are not uniform in occurrence. In spite of the decrease of average abundance during the period 1941 to 1953, no trend appears to have developed. On several occasions the base-period average has been exceeded, in one year (1944) by 21 percent.

Yellow perch.—As with other species, accurate estimates of the abundance of perch could not be made prior to 1930. Statistics of total production, however, indicate high abundance in 1927 and 1929 (Table 1). Although production does not provide a good measure of abundance, the variation seems to be greater than the changes in fishing effort indicated by walleye production would bring about. The relatively low production prior to 1926 may have reflected low abundance, poor market, or failure of the gear to take the fish in quantities.

After 1930 the wide fluctuations of availability were marked by extreme lows in 1930, 1941, 1950, and 1951, and highs in 1937 to 1939, 1944, 1952, and 1953 (Tables 4 and 5, Fig. 4). Following the high in 1944, availability tapered off to an all-time low of 21 percent of the base period in 1950. There followed a rapid recovery to the unprecedented highs of

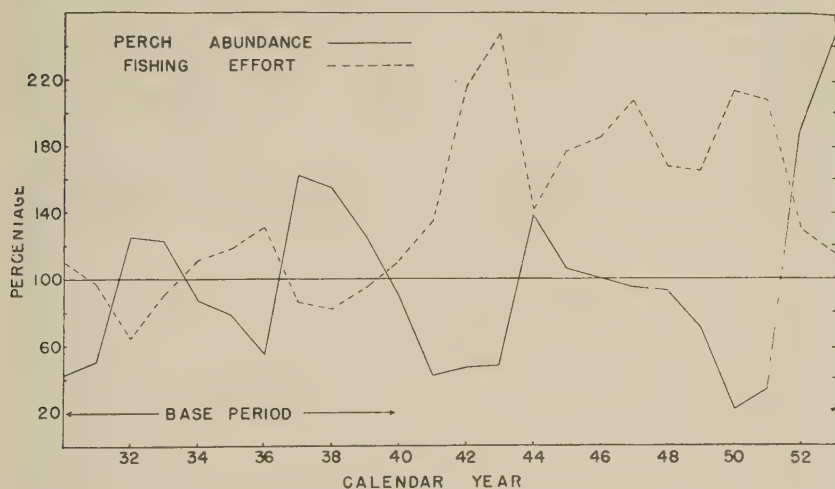


FIGURE 4.—Abundance of yellow perch and total summer fishing effort in the Red Lakes, 1930 to 1953, expressed as percentage of the 1930-1940 average.

191 and 248 percent in 1952 and 1953. During the 13-year period following 1941, the average abundance was 5 percent below that of the previous 11-year period. The large annual changes culminating in a very high level of availability do not suggest any relationship between increased fishing effort and abundance nor any pattern of fluctuation.

Goldeye.—Goldeyes, which have been of minor significance in recent years, were abundant at various periods (Tables 4 and 5). In 1933 goldeye reached an all-time low in abundance—1 percent of the base-period aver-

age. An upward trend which started in 1934 reached the record high of 31.4 pounds per lift or 257 percent of the base average in 1936. Relatively high availability was maintained until 1941, when a decline set in. This irregular but pronounced downward trend culminated in a 1951–1953 level of availability only slightly above the all-time low. Average abundance in the 1941–1953 period was 43 percent of the 1930–1940 base-period average. In view of the decline of this species in other waters coincident with increased fishing pressure, the current trend in Red Lakes may indicate the eventual elimination of the species as a commercial fish. Recovery from the previous low of 1932–1933 suggests, however, that extreme fluctuations are possible without elimination of the fish. If this interpretation is correct, the goldeye may again become a fish of commercial importance.

Other species.—The northern pike like other species has shown a wide fluctuation in availability, but the most obvious change during the 1930–1953 period has been the appreciably higher abundance in recent years (Table 5). Only once since 1938 has the abundance been less than the base-period average and in some years it has exceeded the average as much as 266 percent (1949). The condition of the population appears to be improving. Evaluation of changes in availability of other species is difficult because they are incompletely vulnerable to the gear. The small-mesh nets fished during the summer are ill-suited for the capture of whitefish. Fish of sizes that could be taken by these nets apparently were more abundant during early years than at present, but abundance estimates for the recent period suggest that the whitefish is now undergoing more or less normal fluctuation at a lower average level. Sheepshead, white suckers, and bullheads cannot be appraised but there is no indication of unusual change.

FACTORS ASSOCIATED WITH CHANGES IN ABUNDANCE OF WALLEYE

Abundance and availability.—Consideration of fluctuations in fish abundance immediately brings up the problem of the relationship between true population density and the actual availability of fish to the fishery. This problem is important because measures of abundance usually are based on catch per unit of fishing effort and because there is evidence in some fisheries that availability to commercial gear is not necessarily related closely to actual population density. In the Red Lakes it is believed that catch per unit of commercial gear is a good index of abundance and that factors of availability other than actual population size do not introduce an appreciable error in the estimates.

Red Lakes are shallow with relatively uniform bottoms and are essentially isothermal throughout the fishing season. Marking studies on the walleye (Smith, Krefting, and Butler, 1952) showed that this species moves over the entire area freely and has no tendency to frequent areas where capture could be avoided. Fishermen set nets at all depths throughout the entire lake and also fish surface sets when fish appear to be running at this level. It is evident that availability of fish on particular nights varies in different parts of the lakes since the success of fishermen varies

in different localities. The pattern of geographical availability, however, changes rapidly and continually with changes in wind and other meteorological factors. It is possible that during the extreme high water stage in 1950 fish may have been somewhat less available to fishermen than in normal years, but consideration of data in following years indicated that the estimate of relative abundance for that year was reasonably accurate.

One factor that may play some part in determining the accuracy of abundance estimates for particular years is change in growth rate of sufficient magnitude to alter the vulnerability of younger groups to the commercial gear (Table 7). When growth rate decreases, abundance for a particular year may appear low in comparison to the previous year, but in

TABLE 7.—Average total length (inches) of walleyes of various ages at time of capture (August 5-16) in commercial nets, 1949-1953

[Size of complete availability to commercial gear, 14.9 inches]

Year of capture	Age group			
	IV	V	VI	VII
1949.....	14.9	15.5	16.7	17.5
1950.....	14.0	15.2	16.6	18.2
1951.....	14.0	15.0	16.5	17.2
1952.....	14.0	15.0	15.5	15.8
1953.....	13.1	14.5	15.2	15.8

the following year will be somewhat higher because there has been a slower recruitment of the first vulnerable year class. Although this circumstance does not impair the calculations with reference to actual commercial availability in a particular year, it may introduce error in the evaluations of the causes of fluctuations.

In an area of intensive fishing, competition between nets can occur and so influence the abundance index when it is expressed in terms of catch per standard unit of effort. The total amount of gill net in the lakes may be as great as 550,000 linear feet and as little as 96,000 feet on individual nights. During the period 1930-1953 the annual average number of five-net units per night varied from 75.4 in 1936 to 305.5 in 1948 (Fig. 5). Within this range of fishing effort an assessment of the importance of gear competition was attempted by comparing the average amount of gear with abundance estimates of walleye for the same year over the entire period. Gear competition should be indicated by a significant negative correlation. Correlation coefficient r was -0.07 ($p = 0.74$). Since it is possible that gear competition might be effective at certain levels of fish abundance and not at others, catch per unit of effort on all individual nights fished was compared to the amount of gear in use on those nights for 10 different fishing seasons which showed a wide range of annual abundance (Table 8). No significant negative correlation was obtained in any year. On the contrary four significant positive correlations were obtained. It is assumed, therefore, that gear competition does not influence the estimates of abundance at the levels of fishing effort expended in Red Lakes.

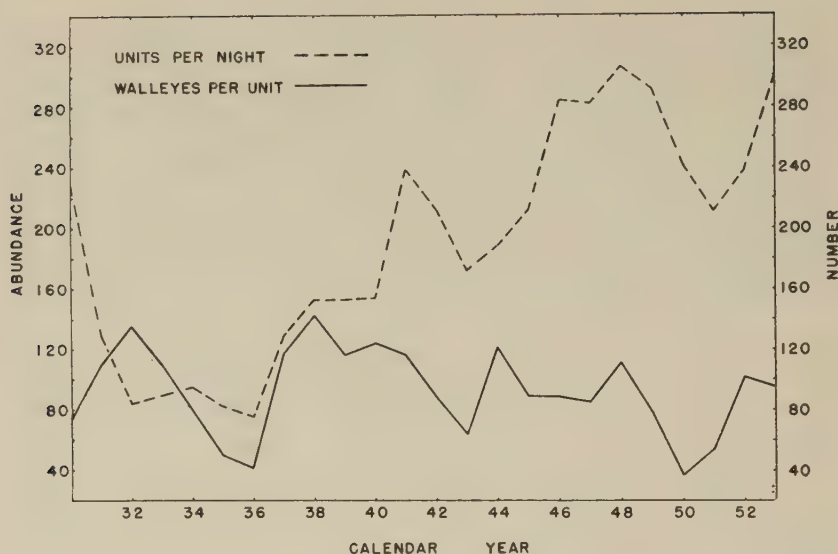


FIGURE 5.—Average number of five-net units per night and average catch of walleyes per unit, 1930 to 1953.

If the indices of abundance reflect actual conditions in the population, the observed fluctuations may arise from several causes. They may be the result of changes in the size of the accumulated stock of fish which are available to the commercial gear or they may result from differences in strength of year classes. Strength of individual year classes may be influenced by size of brood stock, abundance of competing species, size of artificial plantings, or climatic factors. Other more complicated ecological relationships may also be of major importance, but the above factors are the only ones on which data are available in the present study.

Changes in accumulated stock.—There is considerable evidence that abundance of various marine demersal fishes is closely associated with changes in fishing effort. Van Oosten, Hile, and Jobes (1946) showed that deep-water trap nets depleted the whitefish in central and southern Lake Huron. Statistical analyses by Hile, Eschmeyer, and Lunger (1951) led them to conclude that fishing effort was not responsible for the observed decline in lake trout in Lake Michigan. Hile, Lunger, and Buettner (1953) found a positive correlation between effort and abundance of the walleye in Green Bay, Lake Michigan.

Data for the 24-year period during which the statistics on walleyes of the Red Lakes fishery have been compiled permit a study of the relationship of fishing load to abundance in the walleye. During the 11 years, 1930 to 1940, fluctuations were extreme but fish abundance was at an average high level. Summer fishing effort increased sharply in 1941 and was maintained until 1953 at an average level 78 percent higher than the

average of the preceding period (Table 5, Fig. 3). For summer and fall effort combined the increase was 50 percent. Abundance of walleyes dropped sharply following this increase in effort but a quick recovery followed in 1944.

Age-groups V and VI of the walleye comprise 75 to 95 percent of the annual commercial catch; age-group VII usually comprises less than 10 percent. In a fishery supported by so few age groups it would be expected

TABLE 8.—Correlation (r) between number of lifts each night and catch of walleye per lift for each year in the period 1943-1953

Year	Abundance index ¹	Number nights	Number of lifts		r	P
			Average per night	Range		
1943	64	85	109	42-144	-0.06	0.5823
1944	121	45	117	20-142	0.18	0.2340
1945	89	50	132	45-155	-0.02	0.7114
1947	85	44	176	101-200	0.47	0.0018
1948	111	33	190	159-218	0.14	0.4354
1949	78	33	184	115-232	0.47	0.0083
1950	37	53	151	15-198	0.27	0.0477
1951	54	59	95	36-128	0.52	0.0006
1952	101	33	149	112-167	0.12	0.5092
1953	95	23	187	43-210	0.24	0.2585

¹ Average catch per five-net unit expressed as percentage of the mean for the base period 1930-1940

that changes of fishing effort would be reflected in the abundance 1 or 2 years later. Abundance estimates were therefore correlated with summer fishing effort during the previous year and with the combined effort 1 and 2 years earlier. No significant relationship was found (1 year, $r = -0.32$, $p = 0.15$; 1 and 2 years, $r = -0.14$, $p = 0.54$). When combined summer and fall effort for the previous 2 years was correlated with abundance the correlation still was not significant ($r = -0.15$; $p = 0.51$). The slight negative correlation with fishing in the previous years suggests some influence of intensity on later fishing but if present, it is minor.

Change in strength of year class.—The age composition of walleyes taken in the commercial and experimental catches from 1949 to 1953 indicates that the strength of individual year classes controls the general level of abundance. It will be noted from Tables 9 and 10 that V- and VI-group fish are the major support of the fishery and that age-groups IV and VII make up most of the remainder. When either the V or VI group is poor, general abundance will be below normal (*i.e.*, average for the period). If both are weak, a very low population is available for harvest. Of the two most important age groups the V group has the greater influence. The low availability of 1950 was coincident with the occurrence of an extremely weak 1945 year class (V group) and of a 1944 year class (VI group) which was weaker than average. In contrast, the year of greatest abundance during the period of observation was 1952, when both the 1946 and 1947 year classes (age-groups V and VI) were above average strength. When the weak 1948 year class (V group) came into the catch

TABLE 9.—*Age composition of the commercial walleye catch from Red Lakes in the years 1949-1953*
[Expressed as total numbers in the adjusted sample¹ and as percentage of annual total]

Year of capture	Item	Year class										
		1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950
1949	Age group.....	IX	VIII	VII	VI	V	IV	III	.....	.....	.....	.....
	Number of fish.....	11	92	407	1,516	2,604	1,206	91	.....	.....	.....	.....
1950	Percentage.....	0.2	1.5	6.9	25.6	43.9	20.4	1.5	.....	.....	.....	.....
	Age group.....	X	IX	VIII	VII	VI	V	IV	III	.....	.....	.....
1951	Number of fish.....	10	26	108	331	841	763	911	53	.....	.....	.....
	Percentage.....	0.3	0.9	3.6	10.9	27.6	25.1	29.9	1.7	.....	.....	.....
1952	Age group.....	.....	X	IX	VIII	VII	VI	V	IV	.....	.....	.....
	Number of fish.....	.....	2	19	61	215	429	3,555	920	.....	.....	.....
1953	Percentage.....	.....	0.1	0.4	1.2	4.1	8.2	68.3	17.7	.....	.....	.....
	Age group.....	.....	.....	X	IX	VIII	VII	VI	V	IV	.....	.....
1954	Number of fish.....	.....	.....	15	73	214	296	3,801	4,342	290	.....	.....
	Percentage.....	.....	.....	0.2	0.8	2.4	3.3	42.1	48.0	3.2	.....	.....
1955	Age group.....	.....	.....	.....	X	IX	VIII	VII	VI	V	IV	III
	Number of fish.....	.....	.....	.....	8	155	105	2,497	4,565	958	201	3
1956	Percentage.....	.....	.....	.....	0.1	1.8	1.2	29.4	53.7	11.3	2.4	0.1

¹ Numbers of fish in each age group were adjusted on the basis of relative abundance of available stock in the year of capture so that numbers represent estimated relative strength of the year class in each year of life

TABLE 10.—Age composition of walleyes caught in experimental gear from the Red Lakes 1949-1953

Year of capture	Item	Year class											
		1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951
1949	Age group.....	IX	VIII	VII	VI	V	IV	III	II	....	....	....	....
	Number of fish.....	3	9	14	46	89	63	290	73	....	....	....	....
	Percentage.....	0.5	1.5	2.4	7.8	15.2	10.7	49.4	12.4	....	....	....	....
1950	Age group.....	....	....	VIII	VII	VI	V	IV	III	II	....	....	....
	Number of fish.....	....	....	1	4	25	47	285	166	23	....	....	....
	Percentage.....	....	....	0.2	0.7	4.4	8.2	49.9	32.6	4.0	....	....	....
1951	Age group.....	....	....	....	VIII	VII	VI	V	IV	III	II	....	....
	Number of fish.....	....	....	....	1	8	175	292	74	27	13	....	....
	Percentage.....	....	....	....	0.2	1.4	29.7	49.5	12.5	4.6	2.2	....	....
1952	Age group.....	....	....	....	....	....	VII	VI	V	IV	III	II	....
	Number of fish.....	....	....	....	....	....	6	94	239	89	77	53	....
	Percentage.....	....	....	....	....	....	1.1	16.8	42.8	15.9	13.8	9.5	....
1953	Age group.....	....	....	....	....	IX	VIII	VII	VI	V	IV	III	II
	Number of fish.....	....	....	....	....	2	2	61	163	97	142	56	35
	Percentage.....	....	....	....	....	0.4	0.4	10.9	29.2	17.4	25.4	10.0	6.3

in 1953, the level of abundance was maintained by the strong 1946 and 1947 year classes which were present as age-groups VI and VII. The abundance in 1949 was below the average and was marked by low contributions from the 1943 year class as VI-group fish.

Similar control of abundance by a few or single year classes has been noted frequently for marine populations and has been pointed out by Hile, Lunger, and Buettner (1953) in the Green Bay walleye fishery. Since it is apparent that strength of year classes rather than fishing effort controls the abundance of commercial fish in the Red Lakes, several factors which may influence this strength have been examined.

Size of spawning stock.—In some marine and anadromous species it has been shown that the size of spawning stock within certain ranges influences the strength of the year class. In most fresh-water species, however, it has not been demonstrated that the strength of a year class is dependent on the abundance of brood stock. Since the greater part of walleyes available to the Red Lakes fishery are members of age-groups V and VI and only a small percentage of these fish are immature, a comparison of the average abundance 5 and 6 years prior to the abundance in a particular year should give some indication of the influence of brood stock on subsequent abundance. In a comparison covering 18 years (1936–1953) there was no significant correlation between strength of brood stock and subsequent abundance ($r = -0.07$; $p = 0.78$).

On the basis of 5 years of collection, eight year classes were ranked according to their estimated relative strength. These rankings were compared to abundance in the year of spawning. Again, no significant correlation could be demonstrated ($r = -0.25$; $p = 0.50$). The strong year classes of 1946 and 1947 were both produced in years when abundance of brood stock was below average and the weak 1948 year class was produced in a year when abundance was above average. The powerful 1946 and very weak 1945 year classes were produced by spawning stocks of about the same strength. On the other hand, there is evidence from shore seining and experimental gill-net catches that the low 1950 stock produced a weak year class. It seems apparent that fluctuations of brood stock within the ranges observed in Red Lakes have no demonstrable effect on subsequent abundance of walleyes.

Changes in abundance of competing species.—It is generally assumed that when species of fish compete for food and room or prey on each other, increase in abundance of one will be reflected by a decrease in the other. In Red Lakes the two most important competitors of the walleye are yellow perch and northern pike. The age distribution of perch in the commercial catch is similar to that of the walleye since age-groups V and VI of both species predominate. Therefore, annual fluctuations in abundance of both species will reflect changes in strength of the same year classes. Comparison of abundance of walleyes and perch in various years (Table 5, Fig. 6) makes it apparent that they fluctuate in the same manner rather than inversely. When the data for 1952 and 1953, 2 years of abnormally high abundance in perch were excluded, there was a highly significant

positive correlation between abundance of the two species during the 22-year period, 1930–1951 ($r = 0.70$; $p = 0.0013$). When 1952 and 1953 were included the correlation was lower but was still significant ($r = 0.538$; $p = 0.01$). Although the abundance data for 1952 and 1953 seem to conflict with the usual pattern, the records of age composition showed that both perch and walleyes had strong 1946 and 1947 year classes. Weakness

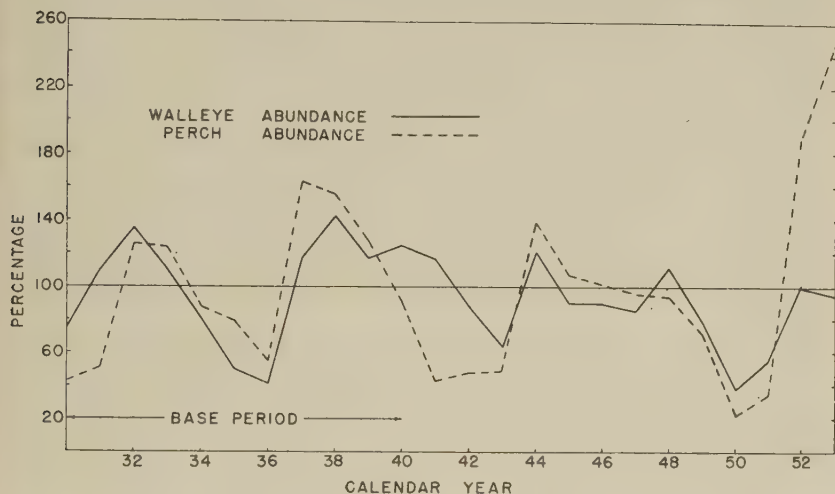


FIGURE 6.—Abundance of walleyes and yellow perch in the Red Lakes, 1930 to 1953, expressed as percentage of the 1930–1940 average.

in the 1948 year class was equally apparent in both species. The difference in relative abundance of the species came from the fact that the strong year classes of perch were far above average while the same groups in walleyes were only moderately above average. These data indicate no detectable antagonism between the two species at the existing levels of abundance. The significant positive correlation suggests an interdependence between perch and walleyes or strong dependence of both species on the same environmental factors. There is some evidence that young walleyes may be dependent on perch fry.

Northern pike may be considered major predators on walleyes and perch but their fluctuations in abundance seem to bear no consistent relationship to changes in the other species (Table 5). Lack of information on age distribution of northern pike in the various years prevents further analysis at present.

Hatchery planting.—Walleye hatcheries are located on Red Lakes, at Waskish on the upper lake and at Redby on the lower lake. Walleye fry were first planted in 1919, and since 1925 have been planted at a rate ranging from 10.9 to 120.2 million fish per year. The influence of planting fry on walleye populations was first critically examined by Hile (1937) in

the commercial fisheries of the Lakes Huron and Michigan. He found no relationship between the number of fry planted and subsequent abundance as indicated by the catch per unit of effort of commercial gear. Carlander (1945) similarly failed to find correlation between walleye abundance and fry planting in Lake of the Woods.

Annual abundance of walleyes in Red Lakes was compared to the size of plantings 5 and 6 years prior to each year from 1931 to 1953 since the annual catch is composed primarily of V- and VI-group fish. A non-significant correlation ($r = 0.016$) was found. When abundance in a particular year was correlated with plantings 5 years earlier, the coefficient was $r = 0.059$. Similarly the relative strength of eight year classes as estimated from scale reading was not correlated significantly with the number of fry planted in the year of hatching ($r = 0.056$). The failure to show a significant relationship between planting and abundance in subsequent years is not surprising in view of the fecundity of the walleye and the large spawning population. Where wide fluctuations of brood stock have no influence on abundance in subsequent years, the annual addition of a very small percentage to the probable natural hatch could hardly be expected to have any effect.

Temperature and precipitation.—If strength of broods is established soon after spawning, temperature and precipitation during this period may be of major importance in determining survival. Therefore the relative strength of seven year classes as determined from scale reading was correlated with total precipitation, mean temperature, and mean minimum temperatures for the 30-day period following the beginning of spawning, the month of May, and the month of June in the corresponding years. No significant correlation could be demonstrated. The very weak 1945 year class was spawned when the lowest spring temperatures of the period occurred but no other suggestive coincidence was observed.

CAUSES OF CHANGES IN ABUNDANCE OF YELLOW PERCH

Causes of changed abundance in yellow perch may be similar to those which determine the level of walleyes. Antagonism between the two species does not seem to be important, as has been noted above. Levels of abundance fluctuate independently from fishing effort, and also appear to be independent of strength of brood stock. At several times during the investigation, greater than normal natural mortality has been observed along the beaches, but these losses have not been associated with any observed change in strength of year classes. It must be concluded that changes in abundance are caused by complex ecological changes not yet explained.

CONCLUSIONS AND IMPLICATIONS FOR MANAGEMENT

The wide fluctuations in both production and abundance of all commercial species in the Red Lakes appear to be largely independent of management procedures except insofar as economic demands have dictated the

extent of annual harvest. Variations in abundance of the principal species, the walleye, occur as a result of natural changes in strength of year classes and are not related to the extent of fishing effort in previous years. The size of brood stock, the extent of artificial planting, and the abundance of competing species have all been shown to have no detectable relationship to changes in year-class strength. Rather, the success of reproduction appears to be controlled by a complex ecological relationship with other species or with climate during the early years of life. Direct competition between species does not seem to be an important factor since changes in yellow perch and walleye show a significant positive correlation and there is no demonstrable relationship with northern pike. Changes in abundance of perch are governed by factors similar to those which control the walleye.

The causes of changes in abundance of goldeye are difficult to assess. The decline since 1942 has been steady and coincident with a substantial increase in the level of fishing, but a similar scarcity occurred in earlier years when fishing effort was much lower. Only future observation will determine whether the current decline is merely a fluctuation or will terminate in the virtual disappearance of the goldeye such as has been observed in some other waters.

The implications of these studies for effective management are varied. If fluctuations of abundance are independent of the amount of fishing effort, regulations on catch and gear should be confined to measures which provide for optimum size at time of harvest of the principal species. The quota on total catch would appear to be beneficial primarily in conjunction with the economics of the fishery and the desirability of reducing the annual fluctuation in production. If the sport fishery should expand greatly in the upper lake, a quota on the commercial fisheries might be needed to permit anglers to take a greater share of the available stock, but the effectiveness of this type of management would have to be demonstrated. It is apparent from the available information that the combination of catches of walleye and northern pike within the same quota limitation is not biologically sound, especially in view of the fact that few anglers catch pike and there appears to be a substantial population of fish of a size larger than can be taken by the commercial gear now in use.³

The value of continuation of the hatcheries for maintenance of the walleyes in the Red Lakes appears to be highly questionable. In view of large quantities of fry removed from the lake for use elsewhere, any effect of hatchery closure probably would be beneficial rather than harmful. Changes in production and abundance since the ending of the fall season do not indicate that any general economic or biological advantage could be gained by reestablishing it.

Management procedures designed to benefit the commercial fishermen should include as primary considerations the prediction of abundance in particular years, limitations on gear and number of fishermen to the extent needed to insure adequate income for the individuals, and gear specifications which would insure maximum combined return from each brood

³ Observed at spawning runs in tributary streams.

of yellow perch and walleye. Specific management for other fish will not be practical unless impounding nets replace the gill nets now in use. A more detailed consideration of the problems of gear specification will be presented elsewhere.

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SOME EFFECTS OF INTRODUCTION OF THE REDSIDE SHINER ON THE KAMLOOPS TROUT IN PAUL LAKE, BRITISH COLUMBIA

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ABSTRACT

The reidside shiner (*Richardsonius balteatus*) was introduced into Paul Lake, British Columbia about 1945 and by 1952 was abundant in the lake. Some effects of this introduction on Kamloops trout (*Salmo gairdneri kamloops*), previously the only other species of fish in the lake, are described. The summer diet of trout underwent marked changes and in 1952 shiners constituted a main item of diet for trout longer than 30 centimeters, fork length. Average stomach volumes of the smaller trout decreased subsequent to introduction of shiners. Growth rate declined and trout did not reach legal size (roughly 20 centimeters) until they were more than 2 years old. Previously, yearling trout had contributed substantially to the fishery. Change in growth rate has intensified the selection by the sport fishery of faster growing fish. A decline in the success of fishing and a drop in angling pressure have resulted in a decrease in catch to less than one-half of the previous annual total. These changes are discussed in relation to predation by shiners on trout fry, predation by trout on shiners and competition for food between shiners and trout.

INTRODUCTION

Paul Lake was barren of fish until 1909 when it was stocked with Kamloops trout (*Salmo gairdneri kamloops*). Until recent years the history of the trout population was similar to that in many lakes of the interior plateau of British Columbia. Since 1930 the lake supported a moderate sport fishery and the size and number of fish in the lake varied with climatic conditions and stocking policy (Mottley, 1941, Larkin *et al.*, 1950). By 1949 the reidside shiner (*Richardsonius balteatus*) was firmly established as a second species of fish in Paul Lake. A rare opportunity was thus provided for evaluating the effects of the introduction of a new species of fish on a population which had undergone previous extensive investigation.

The shiner was introduced into upper lakes of the chain in which Paul Lake lies, probably some time after 1930. Morphological studies of the shiners in Paul Lake (Lindsey, 1953) suggest that first introduction may have occurred from upstream in 1945. In 1948 shiners were sufficiently abundant in Paul Lake that small collections were made for study, and

in 1949 they were in large numbers around the shores. Some attempts were made from 1950 to 1952 to estimate the size of the shiner population by means of marking experiments. However, marked fish exhibited such highly local movements that no assumption of random mixing of marked individuals from different trapping areas could be justified. One such attempt involved the marking of 1,913 yearling and older shiners in June 1952. The shiners were caught in nine small minnow traps set at different points around the lake shore. All recaptures of fish were from the same trap in which they were originally taken. The population in the immediate vicinity of each trap was estimated at approximately 15,000 individuals. On the basis of the area each trap fished it was estimated that the shiner population of Paul Lake probably comprised several million individuals in 1952. Undoubtedly the shiners had occupied their new environment with explosive rapidity.

ECOLOGY OF THE REDSIDE SHINER

Lindsey (1953) has summarized many features of the ecology of the redside shiner in British Columbia lakes. This species occurs in portions of the Fraser, Columbia, and Skeena drainages that have been accessible to fish in the recent geological period. Within its range it occurs in a wide variety of habitats, including large lakes, moderately swift streams, and small ponds. It has been deliberately introduced into a few lakes as a forage species. In some environments shiners may attain a maximum size of approximately 17 centimeters, in most lakes the adults are 5 to 10 centimeters long. Ages of adults probably range from 2 to 4 years. Spawning takes place over a period of 7 to 10 weeks beginning sometime between late May and the end of June. In lakes the eggs are usually broadcast over submerged aquatic vegetation. The redside shiner consumes a wide variety of organisms from the plankton and bottom fauna; surface insects are taken when available. Shiner fry subsist on diatoms, copepods, ostracods, and other small plankton organisms. In these respects the shiner resembles the Kamloops trout in its diet, and frequently Kamloops trout and shiners were found to be feeding on the same things when both were collected at the same time and place. On several occasions shiners have been observed feeding on trout fry.

In lakes, shiner fry show a marked tendency to remain close inshore during the daylight hours. Even the adults are most plentiful in the littoral zone in midsummer and rarely are taken in deeper offshore waters. The habits of shiners in the winter are largely unknown, but a few casual observations suggest that they move offshore and become relatively inactive.

From the foregoing it is apparent that interrelationships of the redside shiner and Kamloops trout are complex, involving at least three separate aspects—competition for food, predation by shiners on trout fry, and predation by trout on shiners. This paper describes some of the effects of the introduction of the redside shiner on the Kamloops trout of Paul

Lake as evidenced by changes in the diet, rate of growth, and vital statistics of the trout population.

FOOD OF KAMLOOPS TROUT IN PAUL LAKE FROM 1946 TO 1952

Table 1 and Figure 1. summarize the composition of the diet of trout in Paul Lake during 1946-1949 and in 1952. For the period 1946-1949 there were no significant differences according to size in the diet of trout over 20 centimeters in length (Larkin *et al.*, 1950). In these years amphipods (*Gammarus* and *Hyaella*) contributed substantially to the large quantities of bottom organisms taken, particularly in the spring and early summer. Plankton comprised roughly two-thirds of the diet in July, August, and September. No fish were in the stomachs of trout taken in the years 1946-1949.

By 1952 the diet of the trout had been modified greatly by the introduction of shiners. From July to September shiners were the main item of food for trout over 30 centimeters long; they constituted a substantial portion of the diet of trout from 25 to 30 centimeters; and they were recorded occasionally in the stomachs of trout from 20 to 25 centimeters long. Shiners taken by trout were almost always relatively large and shiner fry were rarely found in trout stomachs. Hence, a single shiner usually contributed 3 cubic centimeters or more to a stomach volume and in consequence the percentage volume of shiners was frequently higher than would be indicated by the number of stomachs in which they occurred. Amphipods were a negligible food source for all sizes of trout. Aside from these important features, the food habits of trout were similar to those observed previous to 1949. For the smallest trout, 20-25 centimeters long, aquatic insects were the dominant food item in May and June; plankton made up roughly two-thirds of the diet and bottom fauna comprised most of the remainder in July and August-September. The same was true for trout of 25 to 30 centimeters, except that fish rather than bottom fauna replaced aquatic insects as the second most important food in July and August-September. Trout from 30 to 35 centimeters subsisted mainly on aquatic insects in the spring but in later months consumed more fish and less plankton than did trout of smaller sizes. Trout more than 35 centimeters long ate substantial quantities of insects in May and June and made fish more than three quarters of their diet in July and August-September.

All of these changes in diet would suggest that competition between Kamloops trout and reidside shiners for food is being compensated in part by predation by larger trout on shiners. This belief is confirmed by comparison of average volume of stomach contents for various sizes of trout in July and August from 1946 to 1952. (Table 2 and Figure 2). Data for the months of July and August were available in all years 1946-1952; data for May and June were not available for 1950 and 1951 and are not included in the comparisons in Table 1. Average volumes of stomach contents for fish 25-30 centimeters long and 30-35 centimeters long did

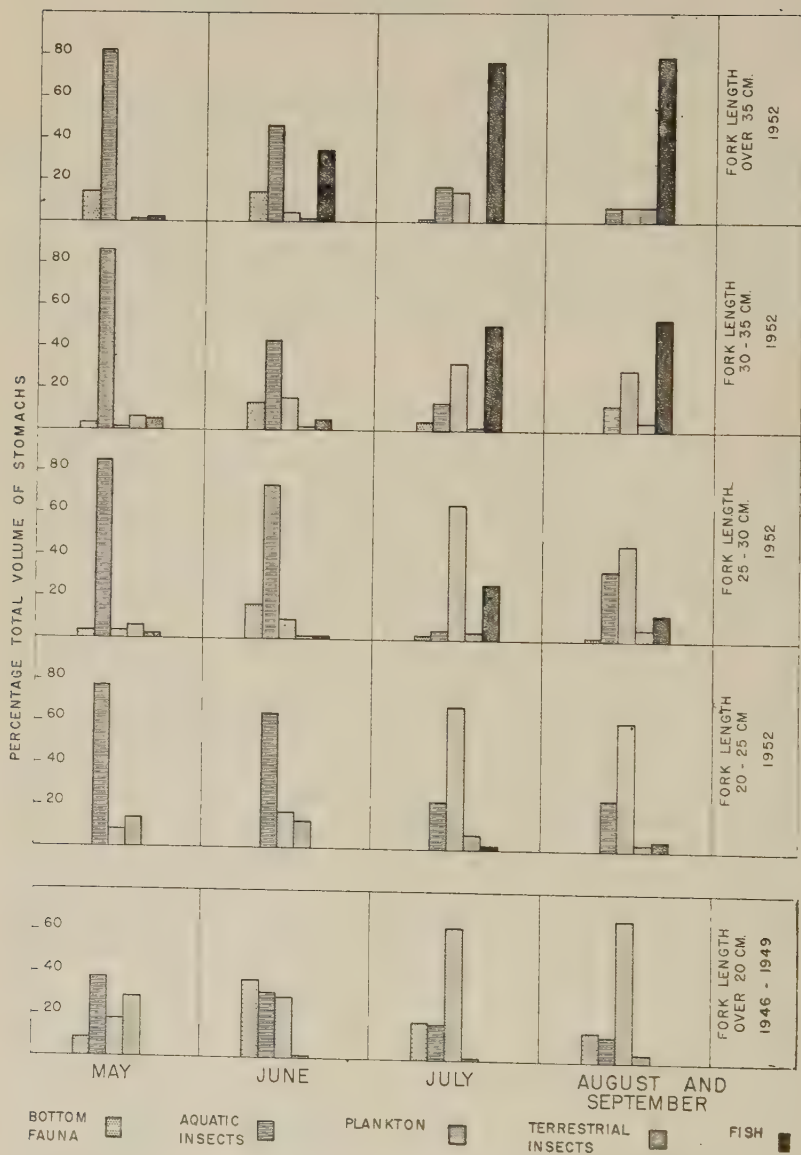


FIGURE 1.—Composition of the diet of kamloops trout in Paul Lake from 1946 to 1952.

TABLE 1.—Average volume of stomach content of Kamloops trout according to month in 1946-1949 and according to month and length group in 1952

Years of collection and fork length (centimeters)	Item	May					June				July					August-September				
		Fish					Fish				Fish					Fish				
		Bottom fauna	Aquatic insects	Plankton	Terrestrial insects	Fish	Bottom fauna	Aquatic insects	Plankton	Terrestrial insects	Fish	Bottom fauna	Aquatic insects	Plankton	Terrestrial insects	Fish	Bottom fauna	Aquatic insects	Plankton	Terrestrial insects
1946-1949 >20	Number of stomachs with item.....	5	10	12	5	..	29	22	14	2	..	32	31	69	6	..	45	46	130	13
	Percentage with item.....	36	71	86	36	..	100	76	48	7	..	31	30	60	6	..	24	25	70	7
	Percentage of total volume.....	9	38	18	31	..	37	31	29	1	..	18	17	63	1	..	14	12	67	4
1952 20-24	Number of stomachs with item.....	..	11	2	6	..	..	15	6	5	..	..	3	15	5	1	..	22	35	5
	Percentage with item.....	..	100	18	56	..	..	88	35	29	..	..	17	83	28	6	..	51	81	12
	Percentage of total volume.....	..	77	8	14	..	..	67	17	13	..	..	23	68	7	2	..	24	61	3
1952 25-29	Number of stomachs with item.....	..	62	16	18	6	..	49	22	6	1	..	3	22	2	2	..	31	45	8
	Percentage with item.....	..	98	25	29	10	..	86	39	11	2	..	12	85	8	8	..	47	68	12
	Percentage of total volume.....	3	85	3	6	2	16	73	9	1	1	2	4	64	3	26	1	33	45	5
1952 30-34	Number of stomachs with item.....	..	48	..	9	4	28	116	62	18	8	..	8	21	6	11	..	38	58	5
	Percentage with item.....	..	100	..	19	8	21	87	47	14	6	..	29	75	21	39	..	46	70	12
	Percentage of total volume.....	3	86	1	6	5	13	63	15	1	5	4	13	32	1	50	..	12	39	4
1952 35+	Number of stomachs with item.....	4	14	..	..	..	17	43	13	..	14	..	6	11	..	9	25	10	8	53
	Percentage with item.....	29	100	..	..	..	35	88	27	..	28	..	33	61	..	80	45	18	14	95
	Percentage of total volume.....	14	82	..	1	2	14	46	4	1	34	1	17	14	..	76	..	7	..	79

not change in any marked degree from 1946 to 1952. Average volume of stomach contents was lower in the later years for fish 20–25 centimeters long but over twice as high for fish 35 centimeters and over. (Mean lengths of the fish in the size range 35 centimeters and over were comparable for the years in question). Apparently, only the smallest trout were affected greatly in the summer by competition with shiners for food; for fish over 25 centimeters long the addition of shiners to the diet compensated for any competition. These features of the diet are discussed with reference to growth rate in a later section.

GROWTH RATE OF KAMLOOPS TROUT IN PAUL LAKE FROM 1946 TO 1952

The data on fork length at capture and the calculated lengths at the end of various years of life for those trout less than 4 years old which had not spawned (Table 3) include information on the growth of the 1943–1951 year classes. All samples were drawn from anglers' catches in the years 1946–1952.

A detailed description of the method used for "back-calculation" of lengths from scale measurements will be published elsewhere by the junior author. Briefly, the method is based on the observation that for Kamloops trout the relationship between the logarithms of scale diameters and fork lengths is described by a straight line with a slope of 45° (after trout have attained a length of about 4.5 centimeters). Variability about the mean regression of scale diameter on fork length is attributed to variation in scale size from individual fish. It may be seen that the relationship is one of simple proportion. Lengths may be calculated from the arithmetic values by means of the appropriate formula. Instead, in this instance a 45° set-square and straight-edge were employed over double logarithmic graph paper. With scale diameter and fork length at capture of each individual as a datum point, lengths were read off opposite the appropriate annuli along the hypotenuse of the set-square. In this manner lengths were estimated on the basis of simple proportion, but without the necessity of performing calculations. The method is a modification of that suggested by Mottley (1942).

Selection of faster-growing Kamloops trout.—For each of the year classes for which data are available for fish caught as members of age-groups I, II, and III (*i.e.*, 1945 to 1949) it is noticeable that the mean calculated length at the end of the first year is largest for I-group fish and smallest for the III-group fish. Thus the faster growing fish on the average are caught at an earlier age. The same trend is evident in comparison of length at the end of the second year for fish caught as members of age-groups II and III. For comparisons of growth, then, it must be born in mind that younger fish in the anglers' catch are a select group of faster growing individuals. This phenomenon is not in any way related to the method of back calculation, since as explained, the nature of the body-scale relationship was determined precisely. Furthermore, the same discrepancies, in the same proportion were present in the actual scale diameters.

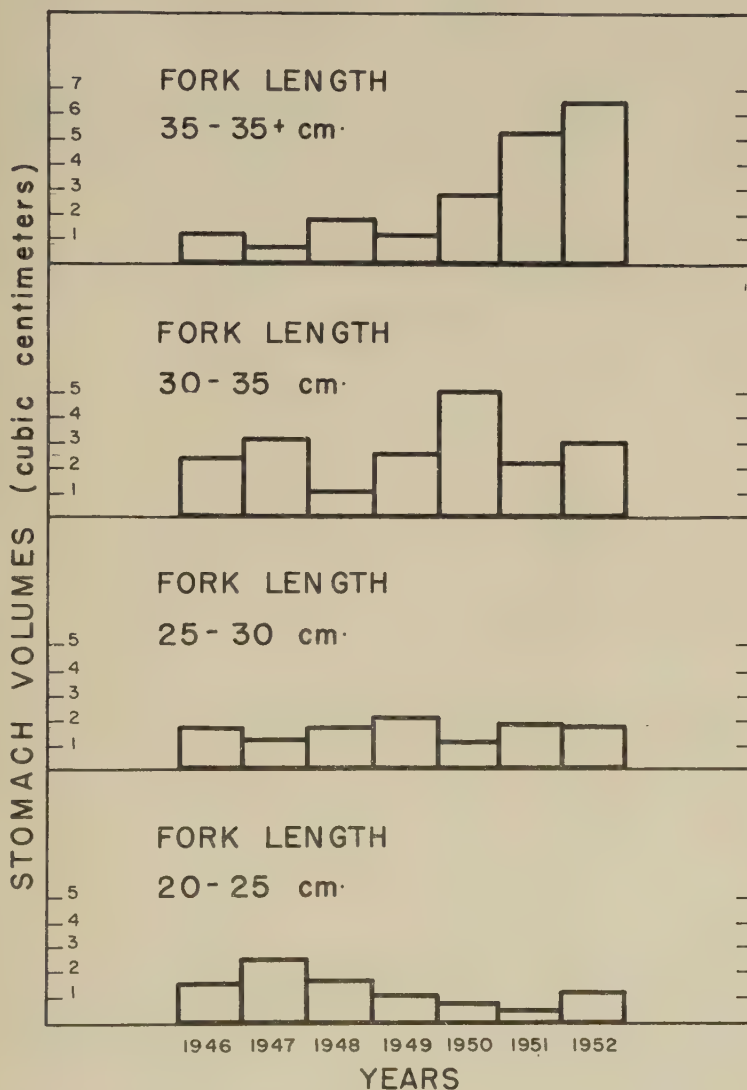


FIGURE 2.—Average volume of stomach contents of Kamloops trout in Paul Lake from 1946 to 1952.

TABLE 2.—Average volume of stomach contents of Kamloops trout of Paul Lake in July and August, 1946-52
[Number of fish in parenthesis]

Fork length (centimeters)	Average volume of stomach contents (cubic centimeters)					
	1946	1947	1948	1949	1950	1951
20-25	1.48 (69)	2.00 (7)	1.59 (7)	1.05 (4)	0.74 (20)	0.51 (14)
25-30	1.77 (60)	1.43 (9)	1.80 (1)	2.13 (6)	1.09 (21)	1.93 (27)
30-35	2.43 (20)	3.15 (9)	1.05 (8)	2.58 (10)	5.10 (12)	2.20 (29)
35 and over	1.21 (45)	0.69 (15)	1.87 (41)	1.20 (14)	2.91 (10)	5.30 (21)
						1.27 (46)
						1.80 (64)
						3.10 (80)
						6.49 (44)

The explanation for this selection is simple. Fish shorter than the legal size limit of roughly 20 centimeters (8 inches) are usually returned to the water by the anglers. Moreover, the anglers tend to employ lures and to fish in such a way that few fish under 20 centimeters are taken. Even among these undersized fish roughly three quarters are longer than 15 centimeters (6 inches). The fishery is thus exerted almost entirely on fish longer than 20 centimeters. This selective angling has a twofold effect. First, samples of all age-groups are biased because the larger individuals

TABLE 3.—*Fork length (centimeters) at capture and calculated lengths at the end of the several years of life for different age-groups of year classes 1943-1951*

Year class	Year of capture	Age group	Number of fish	Length at capture	Calculated length at end of year of life		
					1	2	3
1943	1946	III	14	38.3	8.3	22.0	31.8
1944	1946	II	40	33.3	8.3	23.2	....
	1947	III	13	36.1	7.9	22.3	30.4
1945	1946	I	167	23.9	9.2	....	....
	1947	II	12	32.2	8.9	24.8	....
	1948	III	28	42.2	7.9	23.3	34.7
1946	1947	I	19	24.2	9.6	....	....
	1948	II	93	36.6	9.5	29.7	....
	1949	III	13	38.8	8.6	23.4	33.2
1947	1948	I	36	23.9	10.3	....	....
	1949	II	35	32.9	8.1	24.4	....
	1950	III	14	35.5	7.4	18.8	31.3
1948	1949	I	33	22.0	9.9	....	....
	1950	II	113	28.3	7.5	21.5	....
	1951	III	134	31.3	7.0	17.7	27.6
1949	1950	I	13	21.4	12.7	....	....
	1951	II	405	26.1	8.7	19.2	....
	1952	III	308	31.1	7.3	15.9	25.0
1950	1951	I	36	22.1	11.7	....	....
	1952	II	121	25.5	7.8	16.6	....
1951	1952	I	9	23.3	10.1	....	....

are disproportionately represented in anglers' catches. Second, selection of faster growing fish gradually modifies the distribution of growth characteristics of the various age-groups remaining in the lake. It is evident that the extent of bias by selective fishing to estimates of mean lengths depends primarily on the rates of growth of the age-groups contributing to the fishery. Growth characteristics of the remaining members of various age-groups may be influenced also by the rate of removal of faster growing individuals during the period of selective fishing. Since it is unknown to what degree these factors may bias estimates of growth, the discrepancies in first-year lengths as determined from different age groups of the same year classes cannot be interpreted precisely.

Some measure of the combined effects of biased sampling and possible modification of growth characteristics is provided by the data summarized in Table 4. It is apparent that there is greater evidence for selection of faster growing fish in recent years. This situation could reflect a greater variability in first-year growth, a more intense fishery, or a downward shift in length at any age. As indicated in a later section, the last alternative seems the most likely.

Growth rate.—Table 3 clearly indicates a major decline in the size attained by Kamloops trout in Paul Lake in recent years. Length at the

TABLE 4.—Percentage differences between first-year calculated lengths of various year classes of Kamloops trout caught at ages I, II and III
[Asterisks indicate where the difference is statistically significant]

Age groups compared	Year class						
	1944	1945	1946	1947	1948	1949	1950
I and II. . . .	...	3.1	1.1	21.3*	24.2*	32.3*	33.3*
I and III. . . .	...	14.1*	10.4	28.1*	29.3*	42.5*	....
II and III. . .	4.8	11.3	9.5	8.6	6.7	16.1*	....

end of the third year of life declined from a peak of 34.7 centimeters in 1948 to 25.0 centimeters in 1952. The drop in the last 3 of these years was most significant in that it was the first time in the history of Paul Lake that the mean length of trout at formation of the third annulus had dropped below 30 centimeters. Similar declines were evident for second-year calculated lengths of members of age-groups II and III. The second-year length of the 1950 II-group fish on the average slightly exceeded legal size, but II-group fish caught in 1952 had averaged only 16.6 centimeters at the end of their second year. The size at capture of age-group III showed a similar decline from 1950 to 1952.

Calculated length at the end of the first year showed little variation for fish of the same age-group in the year classes listed in Table 3, probably because of the selective action of the fishery, particularly for I-group fish. If in recent years growth rate was low in the first year and this fact was disguised by selection, then it follows that the smallest fish at age I did not attain legal size by age III. This assumption may in part be true but it seems unlikely that selection would disguise such a major difference in growth rate as indicated by the data for lengths attained at formation of the second and third annuli. It is more plausible to hypothesize that the average size attained by trout in their first year has not changed significantly in recent years in Paul Lake.

In contrast to the high degree of uniformity in first-year growth of Kamloops trout of the same age-groups it is apparent that in recent years a marked decline has occurred in second-year growth. The calculated mean increment of growth during the second year for fish caught at age II ranged from 14.0 to 20.2 centimeters for the year-classes 1944 to 1948,

but for the 1949 and 1950 year classes it was 10.5 and 8.8 centimeters, respectively. For III-group fish the second-year increment fell from values ranging from 10.7 to 15.4 centimeters for the 1944 to 1948 year classes to 8.6 centimeters for the 1949 year class. In consequence, in most recent years the majority of trout did not attain legal size until they had exceeded at least 2 years of age, and selection by the fishery of faster growing I-group fish became more evident.

However, in spite of the decline in fork length attained at age III, there is some suggestion of an increase in recent years in mean growth increment during the third year of life. The values ranged from 8.1 to 11.4 centimeters for the 1944 to 1946 year classes (III-group fish caught in 1947, 1948, and 1949) but from 9.1 to 12.5 centimeters for the 1947 to 1949 year classes (III-group of 1950, 1951, and 1952.) Similar trends were evident in small samples of IV-group fish.

These various lines of evidence indicate that introduction of shiners (probably in 1945) commenced rather abruptly in 1950 to affect growth of trout. The following concurrent results were observed:

1. Decreased growth during second year of life.
2. Decreased size attained by age II.
3. Decreased size attained by age III, but increased growth during third year of life.
4. More evident selection by the fishery of faster growing yearlings.

It should be emphasized that a complex of factors probably affected estimates of growth of the various age-groups from which samples of the anglers' catches were drawn in the different years. For instance, selection by the fishery of faster growing trout and the interrelated effects of rate of exploitation and variability in growth rates probably complicated the vital statistics of the trout population. However, regardless of the degree to which any factor may have biased estimates of growth, the available evidence clearly suggests that introduction of shiners was primarily responsible for sharply decreased growth of Kamloops trout in recent years in Paul Lake.

ANGLERS' CATCH STATISTICS

Age distribution in anglers' catch.—The striking changes in age distribution of Kamloops trout of Paul Lake in anglers' catches from 1946 to 1952 (Table 5, Figure 3) can be related to two major factors: (1) variation in numerical strength of year classes; (2) reduced rate of growth following introduction of redside shiners. From the early 1930's until 1948 Paul Lake received an annual planting of 200,000 Kamloops trout fry, except for 1945 and 1948. In these two years the lake was not stocked, but major floods allowed an unknown quantity of natural spawning in the tributary creeks and in consequence two dominant year classes were recruited to the fishery (Larkin *et al.*, 1950). The 1945 year class contributed over 60 percent of the catch as I-group fish in 1946, made a large contribution as age-group II in 1947, as age-group III in 1948, and as age-group IV in 1949. The 1948 year class made a substantial contribution

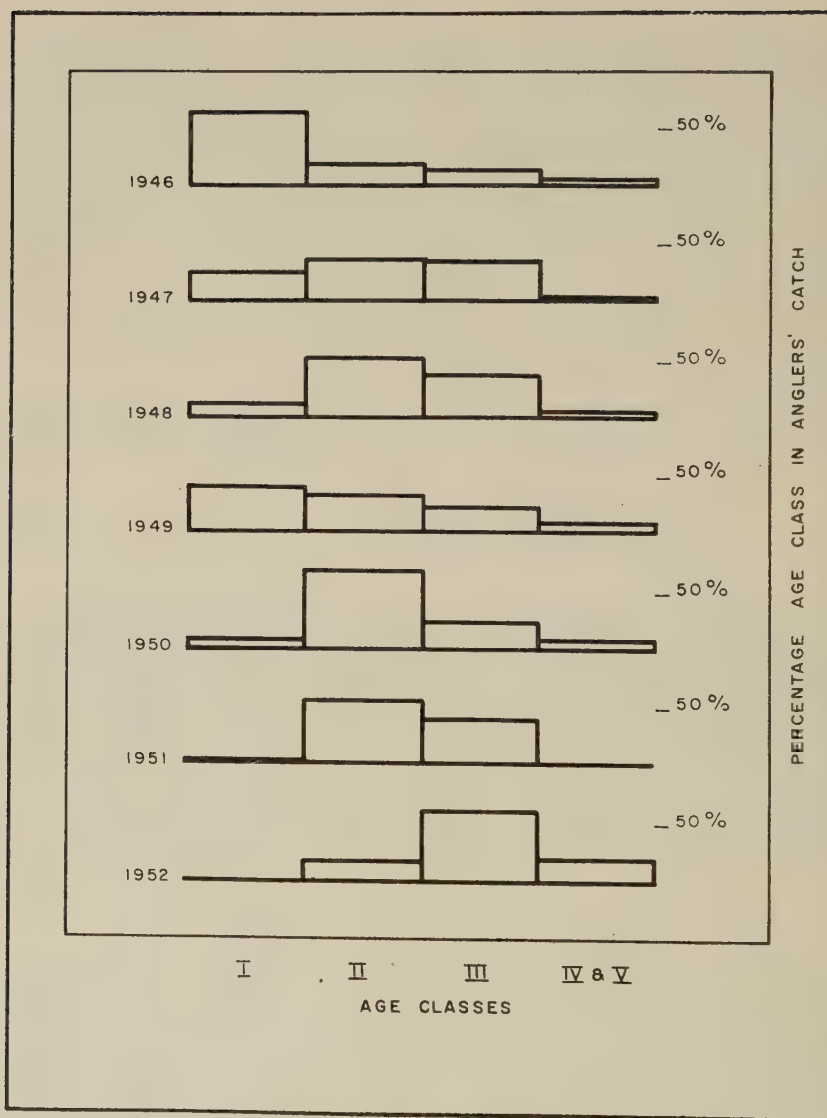


FIGURE 3.—Percentage age composition of Kamloops trout in anglers' catch in Paul Lake, 1946 to 1952.

as age-group I in 1949 and thereafter was clearly much stronger than its predecessors. Beginning in 1950 it became difficult to separate the relative significance of year class strength and decreased growth rate as factors influencing age distribution in the anglers' catch. The poor showing of yearlings in 1950 might be attributed to overshadowing by the 1948 year class (age-group II) but the negligible proportion of yearlings in the 1951 and 1952 catches and the small fraction of II-group fish in 1952 undoubtedly reflect the slow growth rate of the trout. In these years few yearlings reached legal size and many of the II-group fish also were not available to the fishery. The stocking schedule for Paul Lake was modified in 1949 to a rotating plan of 300,000, 100,000, and 200,000 fry in consecutive years beginning in 1949, but this plan was largely negated by the addition to artificial stocking of unknown amounts of natural spawning in each of the first three years. In any event there is no observable effect of this plan in Table 5.

TABLE 5.—Percentage age distribution of Kamloops trout in anglers' catch in Paul Lake, 1946-1952

Year	Percentage of anglers' catch in age-group			
	I	II	III	IV and V
1946.....	63.0	19.7	12.3	4.9
1947.....	24.4	36.7	34.4	3.3
1948.....	10.6	50.2	36.2	3.0
1949.....	38.1	31.0	21.1	9.8
1950.....	6.0	67.3	20.6	6.0
1951.....	3.3	56.6	39.2	1.6
1952.....	1.3	18.4	60.4	19.9

Catch success.—A partial creel census (Wednesdays and Sundays) conducted in 1952 provided data for an estimate of the yield of Kamloops trout to the sport fishery. Available data for the years 1933-36 and for 1949 indicate that the yield of trout did not fall below approximately 9,000 pounds in earlier years nor did it exceed approximately 11,000 pounds in later years, even with a much more intensive sport fishery in 1946-50 (Larkin *et al.*, 1950).

In 1949 the fishing effort was 3,000 boat-days, the catch per boat-day was 3.7 fish, and the average weight of the fish was 1.01 pounds. Total catch in 1949 thus was estimated as 11,200 pounds. In 1952, catch per boat-day was 2.7 fish; average weight of fish was 0.72 pound. If we assume the same number of boat-days in 1952 as in 1949, the catch of trout in 1952 can be estimated as 5,800 pounds—roughly 56 percent of that in 1949. However, the catch was probably much below this estimate. Lodge operators and Game Department field staff reported that poor success discouraged many anglers from fishing Paul Lake and that the total number of anglers in 1952 probably was much less than that recorded for 1949. Extrapolation of available records would suggest a total fishing effort of less than 1,500 boat-days. On this basis the estimate of the 1952 catch

of trout at Paul Lake becomes only 2,900 pounds, approximately 30 per cent of the average catch in the years prior to 1949.

Studies of age distribution in the anglers' catch and fishing success supply abundant evidence that introduction of shiners to Paul Lake had adversely affected the sport fishing to a startling degree by 1952. According to local reports it was worse in 1953.

MANAGEMENT OF TROUT LAKES WITH POPULATIONS OF REDSIDE SHINERS

During the last few decades several introductions of the redbside shiner have been made into British Columbia lakes which previously contained only Kamloops trout. The four largest lakes of the Paul Lake chain (Hyas, Pemberton, Pinantan, and Paul), Jewel Lake and Wilgress Lake near Grand Forks, Rosebud Lake near Nelson, and Stevens Lake near Cranbrook may be cited as examples. Each of these lakes had at one time produced large Kamloops trout (in Jewel Lake fish over 40 pounds were reported shortly after the turn of the century) and in each lake the average size of trout had declined as natural spawning and artificial stocking increased the population. Apparently, shiners were deliberately introduced by well-meaning anglers into some of these lakes, whereas in others the shiners were accidentally introduced through illegal use as live bait. Almost without exception, local reports have been to the effect that trout fishing became very poor after the shiners became abundant, and in only a few lakes have fishing conditions subsequently improved. Because many formerly excellent trout fishing lakes in the province have suffered this fate, the problem of rehabilitation is significant to those responsible for sport-fish management.

The relationship between redbside shiners and Kamloops trout involves at least three types of interaction: predation by shiners on trout fry; predation by trout on shiners; competition for food between the two species. The first of these aspects has not been evaluated in the present study but from casual observation it would appear that predation by shiners on trout should not be dismissed lightly. It is doubtful whether predation by the present trout population would significantly affect the numerical abundance of the shiner population of Paul Lake. Since the large stock of Kamloops trout in Paul Lake did not deter the multiplication of the first few immigrant shiners it most certainly would make little inroad into the present population of several millions. Shiners in the shallowest water occupy a niche that apparently is uninhabitable to the large predator trout during the summer season. As fry, shiners feed on plankton which is not likely to be in limited supply and as adults they crop off bottom organisms with greater efficiency than do trout. The disappearance of amphipods from trout stomachs in recent years suggests that this once important source of trout food is now exploited almost exclusively by shiners. By competing with trout that are turning to bottom organisms to supplement an early diet of plankton, shiners have caused the loss of the equivalent of at least a year's growth for the trout. Most trout now attain legal size during the third year of life (some individuals in the

fourth), whereas in former years the fishery in the late summer months was to a substantial degree dependent on yearling fish. Competition may be compensated in part by an increase in growth rate when trout attain sufficient size to utilize the larger shiners as food, but some of the benefits of this compensation are lost by exposure of the trout to an additional year of natural mortality before they enter the fishery. That mortality during this additional year may be great is indicated by the low catch per boat-day of 1952 and 1953.

The effect of the redbside shiner on the Kamloops trout of Paul Lake may not be typical of that in other bodies of water in British Columbia and elsewhere. Pinantan Lake, the limnology of which has been described by Rawson (1934), has recovered from a decline in trout fishing which followed the introduction of shiners. The lake is eutrophic and may provide such an abundance of food organisms for both shiners and trout that competition for food is not as intense as in the mesotrophic Paul Lake where food production is confined to a narrow littoral zone. Beginning in November 1953 Paul Lake will be stocked with marked 8-inch Kamloops trout in a program of experimentation and rehabilitation.

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Mr. I. Barrett directed the field research in 1952. All stomach analyses for 1950-1952 and preparation and mounting of scale specimens taken in 1952 were the responsibility of Mr. J. Terpenning.

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LIFE HISTORY OF THE BLACK CRAPPIE OF LAKE GEORGE, FLORIDA

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ABSTRACT

A study of the life history of the black crappie *Pomoxis nigromaculatus* (LeSueur), from Lake George, Florida, was made in 1949 and 1950. Few previous attempts to determine the age of fish from Florida waters have been made because of several difficulties in reading scales. Scale readings of 943 black crappie revealed that the 1947 and 1948 year classes were stronger numerically than the 1949 year class. The readings also indicated that few fish reached the IV group or older. Males and females showed only minor differences in growth. Calculations of growth from scale measurements yielded the following estimates of length at the end of the first five years of life: first—4.4 inches; second—8.1 inches; third—9.9 inches; fourth—11.5 inches; and fifth—12.5 inches.

Determination of age and growth from length-frequency distributions of 15,575 fish indicated that the crappie had an average length of 5.5 inches in their first year, 8.5 inches in the second year, 10.3 inches in the third year, and 11.7 inches in the fourth. Examination of scales showed that the black crappie made most of its annual growth from April through November; length-frequencies indicated growth from May through October. The black crappie of Lake George grew at a rate similar to that of other stocks from southeastern waters.

The sex ratio varied from month to month during the year; females outnumbered males in every month but July and August during 1950. Most of the males and females became ripe in February, March, or April. The crappie spawns for the first time at the age of 2 years as no male crappie less than 7.0 inches in total length and no females less than 8.0 inches long were found in spawning condition.

Graphical and tabular representations are given of the length-weight relationship. Factors for converting from standard to total length and from total to standard length were derived from measurements of 1,950 crappie.

The average number of pounds of crappie caught per seine haul in Lake George varied almost inversely with the average water temperature. The greatest catches occurred during November, December, and January in the 2 years of the study.

INTRODUCTION

Commercial fishermen had caught crappie and other fresh-water fish from Lake George for a number of years, when on October 1, 1946, the Florida Game and Fresh Water Fish Commission put into effect regulations prohibiting the sale of the black crappie, as well as other game fish. As a result of court actions fishing continued until January 1948 at which time it was stopped with minor exceptions. In 1949 this study of the black crappie was started to gain knowledge about their age, growth, and breeding cycle. It was recognized that regulations pertaining to this im-

portant game and commercial species needed to be based upon scientific principles if the greatest recreational and economic benefits were to be gained.

Lake George, in which the major part of the commercial fishing of the St. Johns River is concentrated, is approximately 72.8 square miles or 46,588 acres in area, as determined by planimeter from U. S. Coast and Geodetic Survey Chart No. 687 (Dequine, 1953). The major portion of the lake is between 9 and 11 feet deep at normal water levels and has a sand, mud, and shell bottom.

METHODS

The fish were taken by means of commercial seines and otter trawls. Two trawls were fished; one was 20 feet wide with a $\frac{3}{4}$ -inch stretched mesh, the other was 35 feet wide with a 1 $\frac{1}{2}$ -inch mesh. The trawls were towed behind a power boat from 10 to 15 minutes at various speeds. The commercial haul seines were approximately 1,600 yards long, including 100 yards of footing circle and a pocket of 2 $\frac{3}{4}$ - to 3-inch stretched mesh. Mesh size in the body or wing was 4 $\frac{3}{8}$ inches. The seines were 55 to 90 meshes deep.

The total lengths of the crappie used in the length-frequency study were obtained in the field and the fish then returned to the water. Measurements were made at many locations on the lake. Samples for any one month were taken from several locations.

The measurements of the crappie were grouped in 1/2-inch size classes. The 5.5-inch class is made up of those fish from 5.3 inches through 5.7 inches long, the 6.0-inch class of those from 5.8 inches through 6.2 inches.

Sex was determined and scale samples were collected in the field or at the Welaka laboratory. Scales were temporarily mounted in water between glass slides and measurements were made along the anterior radius of the projected image of the scale at the magnification $\times 40$. The direct-proportion method was used to calculate the growth of the fish.

GROWTH OF THE BLACK CRAPPIE AS DETERMINED FROM SCALES

Few attempts have been made to age fish of Florida. Dr. O. Lloyd Meehan (personal communication) attempted to determine the age of largemouth bass, *Micropterus salmoides floridanus* (Le Sueur), and other species from the St. Johns River. He found that erosion of the scales made it impossible to interpret the scales of many of the fish. Scales of the bluegill, *Lepomis macrochirus pupureus* (Cope), and redear sunfish, *Lepomis microlophus* (Gunther), were sent to other workers in 1948. Dr. Donald F. Hansen (personal communication) of the Illinois State Natural History Survey offered little hope for determining the age of the bluegill by the scale method. Dr. Richard Stroud (personal communication) of TVA was of the same opinion. Dr. Stroud thought that a series of scales from the black crappie had possibilities for use in growth studies.

The greatest difficulty encountered in reading scales of the black crappie

was the apparent failure of some fish to form annuli on their scales. For example, a few had reached 10.0 to 11.5 inches (total length) without forming an annulus, whereas scales from other fish of the same size had as many as 2 or 3 annuli. Still other scales had only slight checks in positions which corresponded to annuli of scales from other fish of equal size. Scales from 12 of the larger crappie could not be read because of erosion which in some fish covered as much as two-thirds of the scale and removed all traces of surface markings, *i.e.*, annuli and circuli, where it occurred. Meehan attributed this erosion to successive spawning of the species.

Age composition and strength of year classes.—The age composition of the individual and combined samples of 943 Lake George black crappie (Table 1) shows that in July, October, November, and December 1949

TABLE 1.—*Age composition of the individual and combined samples of Lake George black crappie collected in 1949 and 1950*

Month	Number of fish in age group							Total
	0	I	II	III	IV	V	VI	
1949								
July	4	49	37	8	1	....	...	99
October .....	....	6	7	1	1	....	...	15
November	4	24	20	5	....	....	...	53
December	5	16	2	3	....	....	...	26
Total for 1949	13	95	66	17	2	....	...	193
Percentage	6.7	49.2	34.2	8.8	1.0	....	...	...
1950								
January .....	....	1	14	23	11	3	....	52
February .....	....	1	33	25	12	4	1	76
March .....	....	....	37	41	15	2	....	95
April .....	....	18	28	42	7	4	1	100
May .....	....	13	42	30	2	2	....	89
June .....	....	9	48	35	7	3	....	102
July	23	7	23	9	3	....	....	65
August .....	....	10	17	1	1	....	....	29
October	1	9	9	9	2	....	....	30
November	21	35	26	24	6	....	....	112
Total for 1950	45	103	277	239	66	18	2	750
Percentage	6.0	13.7	36.9	31.9	8.8	2.4	0.3	...
Total for 1949-1950								
Percentage	58	198	343	256	68	18	2	943
	6.2	21.0	36.4	27.1	7.2	1.9	0.2	...

49.2 percent of the fish were in age-group I (year class 1948), 34.2 percent in age-group II, 8.8 percent in age-group III, and 1 percent in age-group IV. The small percentage in age-group 0 (6.7 percent) was presumed to be due to net selectivity.

In 1950, year-class 1948 again contributed the largest percentage of the fish (36.9 percent, age-group II). Age-group III had 31.9 percent of the total instead of the 8.8 percent of 1949. Age-group I had 13.7 percent as compared to the 49.2 percent of 1949. Age-group IV accounted for 8.8 percent of the fish, age-group V for 2.4 percent, and age-group VI for 0.3 percent. Age-group 0 had 6.0 percent—approximately the same as 1949.

The 1948 year class remained strong during the period data were taken (49.2 and 36.9 percent of the total collections). The 1947 year class also was strong both in 1949 (34.2 percent) and 1950 (31.9 percent). The 1949 year class was by comparison weak, since as age-group I in 1950, it made up only 13.7 percent of the total collection.

Growth in length.—The scales collected from 379 males and 499 females during 1949 and 1950 revealed no great difference in the growth rate of the sexes of the black crappie (Table 2). On the whole the discrepancies between the calculated lengths of the sexes computed from fish of the same age for corresponding years of life were randomly distributed. Sex differences in the grand average calculated lengths during the first 4 years of life varied only from 0.1 inch to 0.3 inch with the males the larger. The 0.5-inch advantage of males over females at the end of the fifth year is of questionable significance because of the small number of specimens. The lengths at capture as well as the calculated lengths showed the males to be slightly larger than the females, but again the differences were generally small and of questionable significance. Stroud (1948) also found the crappie in Norris Reservoir did not show significant differences in growth of the sexes.

The growth of the black crappie from Lake George may, therefore, be described from figures for the sexes combined (Table 3). The general growth based on the grand average calculated lengths for all age groups (bottom of Table 3; and Fig. 1) indicates that the greatest growth in length took place during the first year of life (increment of 4.4 inches). The increments decreased during the next 4 years to 1.0 inch in the fifth year of life. The calculated length at the end of 6 years (12.1 inches) was less than that at the end of 5 years (12.5 inches), probably because of the small number of fish (2) in age group VI. The crappie attained a mean length of about 8 inches in 2 years, 10 inches in 3 years, and were nearly 12.5 inches in 5 years.

The calculated lengths of the fish (Table 3) do not agree with the corresponding lengths at capture. This discrepancy can be explained in age-groups 0 and I by net selectivity since many of the small fish of these ages escaped through the nets; thus, those captured were larger than the true average sizes of the age groups. Furthermore, the figures on length at capture are averages for several months and thus, were affected by the growth during the season after annulus formation.

It is not known to what extent the comparatively heavy harvesting of the larger sizes of the younger year groups affected the estimate of the growth rates of the crappie. Presumably the slower growing fish would have a better chance of reaching old age because they would be protected from the seines in their early years by their small size.

Still another factor of probable, but undetermined, importance in the discrepancies between calculated lengths and lengths at capture was the method of calculation (direct proportion). The assumed constant ratio between scale radius and body length may not represent the true relationship.

Time of annulus formation and progress of season's growth.—A study of

TABLE 2.—Average calculated length (inches) and increment of length for each year of life of the male and female black crappie collected from Lake George in 1949 and 1950

Age group	Number of fish		Total length at capture		Calculated length at end of year of life											
					1		2		3		4		5		6	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female		
0.....	16	20	7.5	7.5	...	...	...	...	...	...	...	...	...	...	...	
I.....	92	97	9.3	9.0	5.8	5.7	...	...	...	...	...	...	...	...	...	
II.....	142	185	10.0	10.0	4.5	4.8	8.7	8.6	...	...	...	...	...	...	...	
III.....	103	144	10.8	10.3	3.9	3.8	7.8	7.8	10.0	9.8	...	...	...	...	...	
IV.....	22	38	12.0	11.8	3.3	3.1	6.7	6.8	9.9	9.8	11.5	11.4	...	...	...	
V.....	4	13	13.0	12.5	3.7	3.3	6.3	6.3	9.2	9.1	11.1	11.3	12.8	12.5	...	
VI.....	...	2	...	12.1	...	2.3	...	4.7	...	7.7	...	9.7	11.3	12.1	...	
Total or average.....	379	499	...	...	4.6	4.5	8.1	8.0	10.0	9.7	11.4	11.3	12.8	12.3	12.1	
Increment.....	...	...	...	...	4.6	4.5	3.5	3.5	1.9	1.7	1.4	1.6	1.4	1.1	...	
Number of fish.....	...	...	...	...	363	479	271	382	129	197	26	53	4	15	2	

TABLE 3.—Average calculated length (inches) and increment of length for each year of life of the black crappie collected from Lake George in 1949 and 1950

[Data for the sexes are combined]

Age group	Number of fish	Total length at capture	Calculated length at end of year of life					
			1	2	3	4	5	6
0.....	58	5.8	...	...	...	...	...	...
I.....	198	9.2	5.8	...	...	...	...	...
II.....	343	10.0	4.7	8.6	...	...	...	...
III.....	256	10.5	3.8	7.8	9.9	...	...	...
IV.....	68	11.9	3.2	6.8	10.0	11.6	...	...
V.....	18	12.7	3.4	6.4	9.2	11.3	12.6	...
VI.....	2	12.1	2.3	4.7	7.7	9.7	11.3	12.1
Total or average.....	943	...	4.4	8.1	9.9	11.5	12.5	12.1
Increment.....	...	...	4.4	3.7	1.8	1.6	1.0	...
Number of fish.....	...	...	885	687	344	88	20	2

the mean increment of growth in length from the time of formation of the last annulus (a virtual annulus was assigned from January 1st to the time of the onset of new growth—Hile, 1948) shows that in 1949 some growth took place in age-groups I and III every month from July through December (Table 4). In age-group II the estimate of growth through December is obviously far too small, but the sample contained only 2 fish; the growth

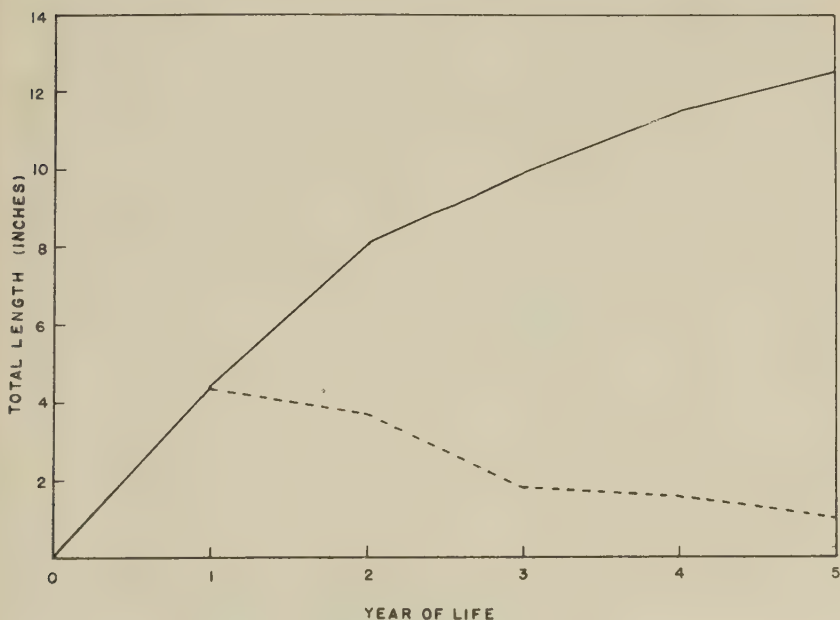


FIGURE 1.—Calculated length (solid line) and increments of length (broken line) of Lake George black crappie.

TABLE 4.—*Annulus formation and progress of season's growth of Lake George black crappie*
[The increments were computed from measurements of marginal scale growth beyond the last annulus]

Year and month	Age group										
	I				II				III		
	Number of fish	Fish with completed annuli		Growth increment (inches)	Number of fish	Fish with completed annuli		Growth increment (inches)	Number of fish	Fish with completed annuli	
		Number	Percentage			Number	Percentage			Number	Percentage
1949											
July.....	49	49	100.0	2.7	37	37	100.0	2.3	8	8	100.0
October.....	6	6	100.0	3.2	7	7	100.0	1.7	1	1	100.0
November.....	24	24	100.0	4.2	20	20	100.0	2.5	5	5	100.0
December.....	16	16	100.0	4.4	2	2	100.0	0.9	3	3	100.0
1950											
January.....	1	0	0.0	0.0	14	3	21.4	0.0	23	2	8.7
February.....	1	0	0.0	0.0	33	22	66.7	0.3	25	8	32.0
March.....	..	..	..	..	37	25	67.6	0.2	41	5	12.2
April.....	18	17	94.4	1.0	28	25	89.3	0.7	42	36	85.7
May.....	13	13	100.0	2.3	42	42	100.0	1.0	30	30	100.0
June.....	9	9	100.0	2.9	48	48	100.0	1.6	35	35	100.0
July.....	7	7	100.0	3.1	23	23	100.0	1.4	9	9	100.0
August.....	10	10	100.0	3.6	17	17	100.0	1.6	1	1	100.0
October.....	9	9	100.0	4.9	9	9	100.0	2.5	9	9	100.0
November ¹	35	35	100.0	5.2	26	26	100.0	2.9	24	24	100.0

¹ Clearly marked checks with the appearance of annuli were found near the edge of the scales of 14 fish collected during November 1950; 8 were in age-group I, 4 in age-group II, and 2 in age-group III. Collections from 1951 which might have shown whether these checks were in fact annuli were not made

of both must have been far below average. In 1950 the data showed the crappie of age-group I grew from April through November without interruption. Age-group II and III exhibited a similar trend of growth with some irregularity.

The greatest average increment from the time of annulus formation for 1949 was in December for age-group I (4.4 inches). In 1950 age-group I had an increment through November of 5.2 inches. Age-group II had its greatest increment in November 1949 and in November 1950. The greatest average increment for age-group III was in December 1949 (3.3 inches) and in October 1950 (1.8 inches). Age-group IV, V, and VI were not satisfactory for this type of analysis because of the small number of individuals obtained and were, therefore, omitted from the table.

A catch of 22 small crappie with an average total length of 3.5 inches was taken by trawl during July 1950. In November 1950, 19 fish in age-group 0 which were taken from seines and trawls averaged 6.9 inches.

Annulus formation occurred during January, February, March, April, and probably in November 1950. Percentages of fish in the different age groups that had completed annuli by the end of April were: age-group I, 94.4; age-group II, 89.3; and age-group III, 85.7 (Table 4). Age-group IV also had 85.7 percent completed.

COMPARISON OF GROWTH OF BLACK CRAPPIE IN LAKE GEORGE WITH GROWTH IN OTHER AREAS

Data from the present study permit a comparison of the growth of the black crappie in Florida with growth in other waters (Table 5). The direct-proportion method of calculating length was used in each of the growth studies of crappies from the papers cited.

The most rapid growth occurred in 211 crappie from Norris Lake. The oldest fish had reached 12.2 inches in 3 years, and had reached 13.7 inches in their fifth year. The first-year growth of these fish was slower than that in Lake George. Crappie from Onized Lake showed a more rapid rate of growth after the second year than was observed in Lake George. This rapid growth could be caused by reduction of population density by the heavy fishing pressure which existed at the time. Cherokee Reservoir crappie showed slower growth than Lake George fish in the first 2 years, but third-year fish had reached 10.3 inches. The growth of 9 black crappie from Hiawassee Reservoir was similar to that of Lake George fish.

It can be seen from the above that the growth of the black crappie of Lake George, Florida is much like that in the reservoirs of the Southeast. These reservoirs are relatively new bodies of water and the favorable growth rate in them has been associated with an abundant food supply as well as the long growing season. The similar growth in Lake George can also be associated with a long growing season and an abundant food supply (Huish 1950¹). In addition, a commercial harvesting industry in the past may

¹ Unpublished report.

TABLE 5.—*Comparison of growth of black crappie in different waters*

Investigation	Location	Number of fish	Total length (inches) in year of life					
			1	2	3	4	5	6
Bennett (1945).....	Onized Lake, Ill.	353	3.4	8.0	11.4	....	....	....
Eschmeyer (1944).....	Chickamauga Lake, Tenn.....	132	2.2	4.8	....	....	....	....
Eschmeyer (1941).....	Norris Lake, Tenn.....	211	5.0	10.9	12.2	....	....	....
Stroud (1948).....	Norris Reservoir, Tenn.....	925	3.2	9.5	11.8	12.7	13.7	....
Stroud (1949).....	Cherokee Reservoir, Tenn.....	85	1.8	7.2	10.3	....	....	....
Stroud (1949).....	Hiwassee Reservoir, N. C.....	9	2.9	7.5	10.2	11.5	....	....
Stroud (1949).....	Douglas Reservoir, Tenn.....	28	4.7	7.0	8.1	....	....	....
Huish.....	Lake George, Fla.....	943	4.4	8.1	9.9	11.5	12.5	12.1

have had the same effect on the fish of Lake George by reducing their numbers as the opening of new waters in the reservoirs had on those in Tennessee.

LENGTH-FREQUENCY DISTRIBUTIONS OF BLACK CRAPPIE

The length-frequency distributions provide a valuable check on the scale method, particularly when scales are as difficult to age as those of the black crappie from Lake George. When growth is reasonably fast and the overlap of the length distributions of successive age groups is limited, the modal lengths of individual age groups frequently stand out in the distribution for all age groups combined. In practice, however, it is frequently impossible to separate the age groups, particularly among the larger fish which grow slowly and make up a small proportion of a population. Large differences in the rate of growth of the sexes of many species also interfere with interpretation. Another difficulty is that some species spawn over a prolonged period of time and thus tend to have broad distribution of length in individual age groups. The black crappie of Lake George, however, lends itself well to this type of study because of its relatively short spawning period, its rapid growth, and the nearly equal rate of growth of the sexes.

Measurements were made of total length of 15,575 black crappie caught in the haul seines and trawls during 1949, 1950, and 1951. In 1949, 11,193 measurements of fish from haul seines were made during 2 weeks of each month of the year. During 4 months of 1950 (January, February, June, and November) 3,824 measurements were made of seine-caught crappie. In February 1951, 513 measurements were made. It was found that seines with the 3-inch minimum size did not catch many crappie which were under 7.5 inches long. Most of the small crappie may have escaped through the 4 3/8-inch stretched-mesh wing of the seine since some crappie were seen to gill themselves in this portion. Therefore, in February 1951, 45 fish were collected by means of a 35-foot trawl in order to establish the first-year growth. The length-frequency distributions for the months in which a collection was made are presented in Figures 2 and 3.

In Figure 2 the growth of the fish was reflected by the movement of the modal peaks from small to larger size groups from month to month. For example, the prominent 9.0-inch size group of January 1949 which represented the fish which had been spawned in 1947 had moved to the 10.0-inch size group in July 1949. By December 1949, this 1947 year class was represented by the peak at 11.0 inches. The 1948 year class, represented a "near mode" at 7.5 inches in March 1949, became dominant in August with a strong mode at 8.0 and 8.5 inches. In November 1950, the 1948 year class was represented by the peak at 11.0 inches. The position of the 1949 year class cannot be detected satisfactorily due to the great abundance of fish of the 1948 year class. (It will be remembered that the scale readings brought out the great abundance of this 1948 year class). On the whole the most rapid growth took place from May through October since the modes shifted more during these months than during the rest of the year.

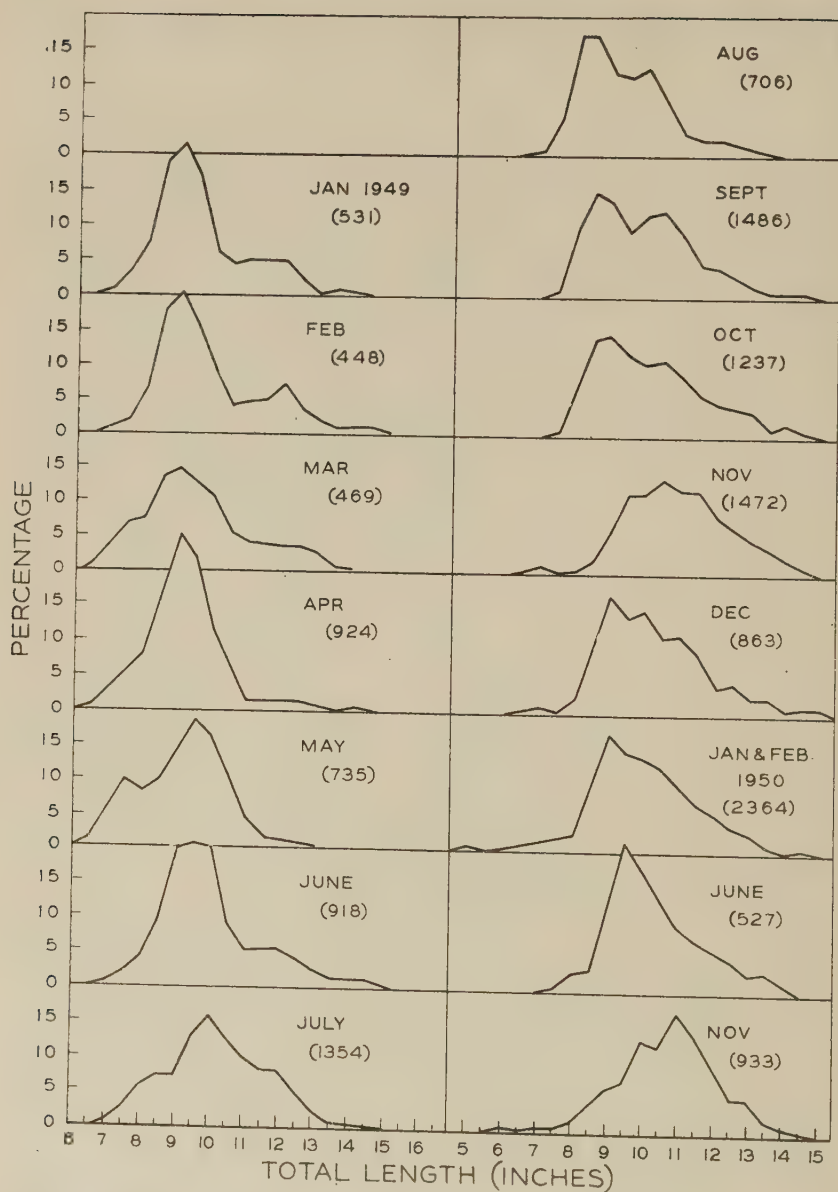


FIGURE 2.—Length-frequency distributions of black crappie from Lake George for each month of study.

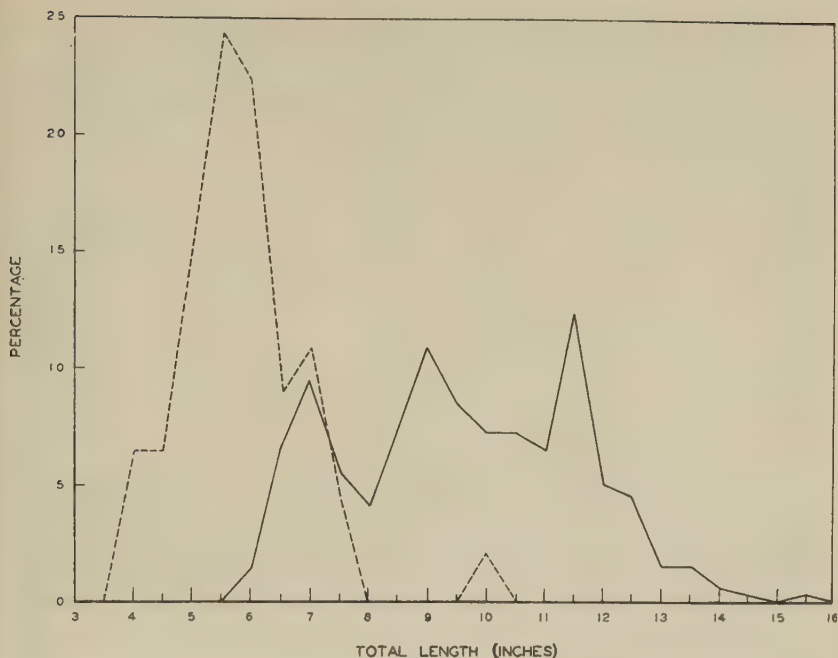


FIGURE 3.—Comparison of length-frequency distributions of black crappie taken from Lake George in February 1951 by haul seines (solid line) and trawl (broken line).

A length-frequency diagram of a sample containing 513 fish from the haul seines and 45 additional fish from the trawl in February 1951 is given on a larger scale in Figure 3. The trawl sample indicates the size of the smaller crappie which escaped the haul seines. Three distinct modes are indicated—the first at 5.5 inches, the second at 9.0 inches, and the third at 11.5 inches. These peaks represent fish belonging to the 1950, 1949, and 1948 year classes, respectively (age-groups I, II, and III). The peak at 7.0 inches in the curve for seine-caught fish represents the capture of larger individuals of the 1950 year class.

On the whole the agreement between modes in frequency distributions and the estimates of lengths of age groups based on scale readings was reasonably good.

SEX RATIO AND SEXUAL MATURITY OF THE BLACK CRAPPIE

Of 904 fish examined, 22 were too small for determination of their sex; 382 of the remaining 882 were males and 500 were females.

In Table 6 it may be seen that the sex ratio by months varied greatly during the period of this study. The percentage of males rose from 31.6 percent in February 1950 to a high of 61.9 percent in July 1950. Of 30 fish examined in October 1950, 30 percent were males.

TABLE 6.—*Sex ratio of black crappie, Lake George, Florida, for various months*

Year and month	Number of males	Number of females	Percentage males
1949			
July	44	56	44.0
November-December	38	37	50.7
1950			
January	13	18	41.9
February	24	52	31.6
March	32	63	33.7
April	37	63	37.0
May	38	51	43.7
June	50	53	48.5
July	26	16	61.9
August	16	13	55.2
October	9	21	30.0
November	55	57	49.1
Total	382	500	43.3

The change in the sex ratio is apparently seasonal and to be attributed only in part to the combined effects of shifting age composition and a change of sex ratio with age. The 1948 year class had more fish for most of the months of the study than any other year group (Table 1). Furthermore, each age group had a lower percentage of males than of females. The percentages of males were 43.1, 41.5, 39.6, 32.9, and 21.1 for age-groups 0, I, II, III, and IV.

The low percentages of males found in February, March, and April appear to be associated with a pre-spawning segregation.

The condition of the gonads was placed in one of the 5 following categories:

Immature: The testis or ovary was small, thread-like, and with no indication of spawning at the next spawning season.

Mature but not approaching ripeness: The gonad was enlarged. The ovary did not appear to have ova present, or in a few the ova were minute and scattered. The testis was somewhat enlarged and whitish. It was considered that these fish would spawn during the next spawning season.

Nearly Ripe: The ovary was large and had many eggs. The eggs were yellow and difficult to extrude by stripping. In the male, stripping was difficult and the gonad was large and white.

Ripe: The ova were more lightly colored than those of the nearly ripe fish. The eggs were easily extruded by stripping. The ovary was much enlarged and frequently filled a large part of the body cavity. The testes of males in this classification were large and white. They were similar to the near-ripe condition except the milt was much more easily extruded by stripping.

Spent: The ovary was flaccid. Ova might be present but they were scattered in the ovary. When the fish was stripped eggs did not appear but occasionally a bloody material was extruded. The testes were large but the solid-white appearance had given way to a translucent quality. Milt was not obtained by stripping except for an occasional individual which gave up a small amount in response to a strong pressure.

The classification of the state of gonads (Table 7) showed that the largest percentages of males progressed from the "mature but not approaching ripe" condition in November and December 1949 to "nearly ripe" in

TABLE 7.—*Gonad conditions of black crappie from Lake George, Florida for the various months*
[Expressed as percentages of total number of fish in each sample]

Year and month	Immature	Mature but not approach- ing ripeness	Nearly ripe	Ripe	Spent	Total Number
Males						
1949						
July.....	....	100.0	....	....	....	44
November-December.....	....	89.5	10.5	....	....	38
1950						
January.....	....	15.4	84.6	....	....	13
February.....	....	33.3	12.5	54.2	....	24
March.....	....	6.2	9.4	84.4	....	32
April.....	8.1	10.8	5.4	75.7	....	37
May.....	....	10.5	2.6	39.5	47.4	38
June.....	4.0	20.0	6.0	4.0	66.0	50
July.....	7.7	92.3	....	....	....	26
August.....	....	100.0	....	....	....	16
October.....	....	88.8	11.1	....	....	9
November.....	....	92.5	3.7	3.7	....	55
Females						
1949						
July.....	....	12.6	....	....	87.5	56
November-December.....	....	100.0	....	....	....	37
1950						
January.....	....	27.8	73.2	....	....	18
February.....	....	7.7	40.4	51.9	....	52
March.....	1.6	22.2	11.1	65.1	....	63
April.....	3.2	8.1	4.8	79.0	4.8	63
May.....	....	15.6	23.5	13.7	47.1	51
June.....	....	15.0	....	....	84.9	53
July.....	25.0	68.7	....	....	6.3	16
August.....	....	100.0	....	....	....	13
October.....	....	100.0	....	....	....	21
November.....	....	100.0	....	....	....	57

January 1950, then to "ripe" in March and April and finally to "spent" in May and June. Development of females to a near-ripe condition occurred in 73.2 percent of the fish in January 1950. During February, March, and April a progression to a ripe condition occurred in a majority of the fish. The percentages of spent fish increased from April through June. The ovaries during July, August, October, and November 1950 were almost all mature but not approaching ripeness; therefore, it can be assumed that the crappie spawned during April, May, and June.

The gonad examinations during February, March, and April 1950, a period at which most mature fish were ripe, were used to determine the size at which sexual maturity was attained. No male under 7 inches was found to be ripe. Two males which were less than 7 inches long were thought to be mature. Three males from 5 to 8 inches long were immature. No female under 8.0 inches was ripe; however, 6 of them less than 8.0 inches were approaching ripeness or were nearly ripe. Three females from 5 to 8 inches long were immature. It appears then that the black crappie of Lake George normally reaches sexual maturity at a length of 7 to 8 inches or at the end of 2 years of life.

FLUCTUATION IN ABUNDANCE

Comparisons of monthly fluctuations in the catch of black crappie per seine haul in Lake George with temperature readings revealed a negative correlation.

The number of pounds of black crappie caught per seine haul from Lake George, as indicated by data collected by members of the Game and Fresh Water Fish Commission, varied widely from month to month. The largest average weight per haul occurred during the winter months (Table 8 and Fig. 4). A low of 25 pounds per haul occurred in July 1948 (no temperatures were obtained for this month). The average increased to a peak from October 1948 through January 1949 and then dropped to a low of 109 pounds per haul in June 1949. The largest average catch per haul (1,013 pounds) was recorded in November 1949, and the smallest average of 1950 was in September (67 pounds). The poundage then began to increase, reaching a peak of 608 pounds in December 1950.

TABLE 8.—*Relationship of total catch of black crappie and catch per haul in Lake George to surface temperature*

Year and month	Total catch (pounds)	Number of hauls	Average pounds per haul	Number of temperature readings	Average temperature (F.°)
1948					
July.....	324	13	25	...	....
August.....	1,341	19	71	16	81.9
September.....	25,760	60	429	21	81.1
October.....	59,237	97	611	9	76.1
November.....	49,005	81	605	4	68.7
December.....	38,659	61	634	12	67.3
1949					
January.....	44,380	74	600	13	63.8
February.....	26,207	67	391	6	64.7
March.....	27,276	84	325	25	69.8
April.....	10,406	66	158	36	71.4
May.....	10,409	93	112	45	79.2
June.....	5,217	48	109	44	81.6
July.....	23,397	189	124	79	84.4
August.....	52,378	124	422	93	83.6
September.....	54,518	145	376	113	82.1
October.....	57,316	148	387	108	77.9
November.....	120,569	119	1,013	91	63.1
December.....	68,900	88	783	62	61.2
1950					
January.....	55,643	110	506	96	67.1
February.....	11,641	46	253	36	65.8
March.....	16,316	48	340	37	62.5
April.....	8,232	31	266	28	68.7
May.....	12,394	84	148	75	78.7
June.....	5,732	77	74	78	83.5
July.....	3,158	36	88	32	82.5
August.....	11,824	100	118	78	82.9
September.....	3,359	50	67	35	81.3
October.....	7,584	32	237	29	76.3
November.....	7,300	29	252	21	70.4
December.....	6,088	10	609	10	55.0
1951					
January.....	7,779	17	458	14	58.2
February.....	2,024	12	169	9	62.1

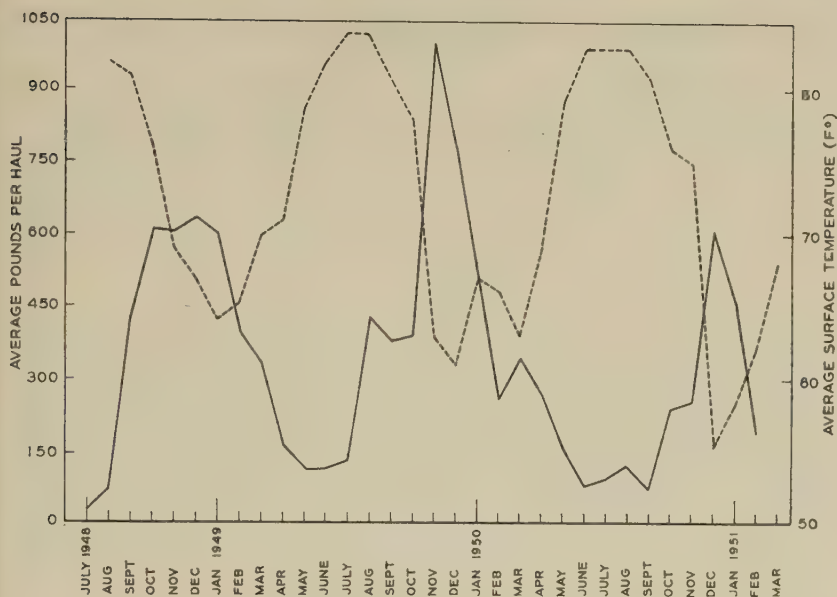


FIGURE 4.—Average number of pounds of crappie per seine haul (solid line) and average surface temperature, F.°, (dotted line) in Lake George.

The crappie was present in greater quantities during periods of low temperature and in lesser quantities during periods of high temperature.

LENGTH-WEIGHT RELATIONSHIP, CONVERSION FACTORS AND COEFFICIENT OF CONDITION

The length-weight relationship of 263 black crappie is presented in Table 9 and Figure 5. The figure has been constructed so that the conversions can be made between standard length in millimeters and total length in inches and between grams and ounces.

The length-conversion factors employed in the preparation of Figure 5 were derived from measurements of 1,950 crappie that ranged in size from 1.7 to 14.6 inches. Two sets of factors were used because of a change in the relationship between total and standard lengths with increase in the length of the fish (Table 10).

Approximate lengths of black crappie at certain selected weights were: 5 ounces—8½ inches; 10 ounces—10½ inches; 20 ounces—12½ inches; 30 ounces—14 inches. The largest fish which weighed approximately 3 pounds measured 15.0 inches.

The coefficient of condition *C* was determined by the use of an alinement chart made by Phenice and Bishop (1950).

TABLE 9.—Length-weight relationship and coefficient of condition of the black crappie from Lake George

Number of fish	Average total length (inches)	Average standard length (millimeters)	Average weight (ounces)	C	Number of fish	Average total length (inches)	Average standard length (millimeters)	Average weight (ounces)	C
2	7.4	141	3.2	50	4	10.8	211	11.3	57
7	7.6	145	4.0	57	13	11.0	214	11.1	52
9	7.8	149	4.3	57	5	11.1	218	11.2	50
7	8.0	152	4.1	52	14	11.3	222	12.7	53
6	8.1	156	4.2	48	3	11.6	226	13.6	54
9	8.4	161	4.6	49	4	11.7	229	15.1	57
11	8.6	164	5.0	49	4	12.0	234	16.4	60
17	8.7	167	5.2	46	4	12.2	238	17.7	60
10	8.9	171	5.6	49	6	12.3	241	17.8	59
15	9.1	175	6.1	50	1	12.5	245	18.0	58
9	9.3	179	6.5	50	6	12.7	249	21.0	63
15	9.5	183	6.8	49	2	13.1	256	23.0	64
18	9.7	186	7.3	49	4	13.5	264	26.7	68
19	9.9	190	8.0	50	1	14.1	276	31.0	69
16	10.2	194	8.6	51	1	14.5	284	33.0	67
8	10.4	203	9.4	53	1	15.0	293	35.0	59
12	10.6	206	9.9	52					

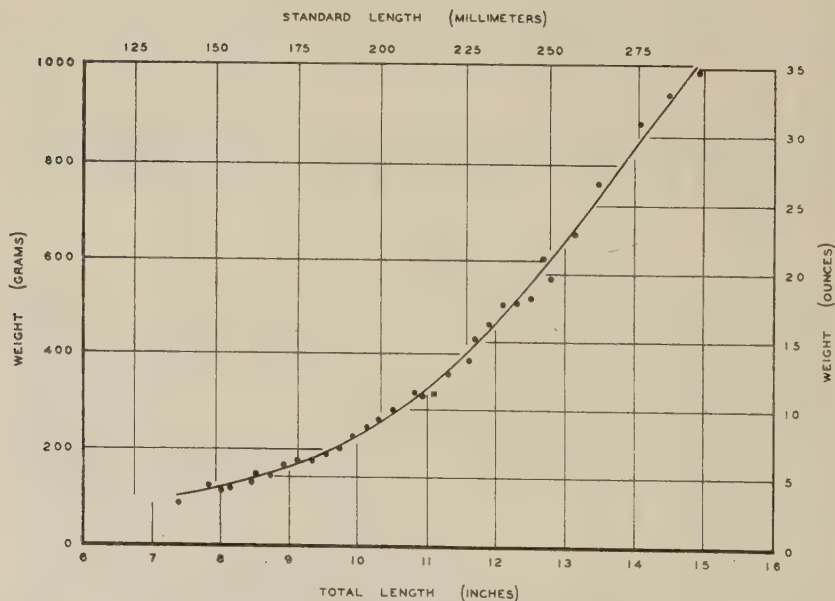


FIGURE 5.—Length-weight relationship of the black crappie from Lake George, Florida. The dots represent the empirical data; the curve was fitted by inspection.

TABLE 10.—*Factors for conversions between total and standard lengths in the black crappie from Lake George*

Length conversion	Length of fish (inches)	
	1.7-10.2	10.3-14.6
Standard to total	1.303	1.300
Total to standard	0.753	0.769
Number of fish	1,088	862

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EFFECT OF SOLAR RADIATION AND OF GRAVEL COVER ON DEVELOPMENT, GROWTH, AND LOSS BY PREDATION IN SALMON AND TROUT

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ABSTRACT

Several earlier researchers have pointed out that trout and salmon fry hatched under gravel are hardier than those reared in a hatchery. The present report confirms these observations, and tries to delineate the effect of certain environmental factors on the embryonic development of salmon fry. Salmon fry (*Salmo salar*) hatched under gravel were better developed, more deeply pigmented, and on the average 15 percent heavier than those hatched in troughs. The average number of vertebrae was significantly influenced by solar radiation and by gravel cover. The separate effects of these two environmental conditions tended to obscure one another. Vertebral malformations were numerous in fry hatched under gravel in total darkness. Mortality, caused by blue-sac disease at the time of the spring run-off of snow water was less among brown trout (*Salmo fario*) alevins hatched in gravel than among hatchery reared alevins. Rainbow trout (*Salmo gairdneri irideus*) fingerlings hatched under gravel were less vulnerable to predators (eels) than fingerlings hatched in hatchery troughs.

INTRODUCTION

During the past two decades numerous investigators have pointed out the relative futility of artificial restocking of trout in waters already containing native trout populations. The latest reviews of this important question are cited: Holloway (1945), Westerman and Hazzard (1945), Hobbs, (1948), Schuck (1948), and Needham (1949). Schuck (1948) showed that in the same river the survival rate of hatchery-reared fingerlings is much lower than that of the wild fingerlings of the same age. He suggested several possible causes for the lower survival of hatchery-reared trout, such as improper diet, lack of exercise, freedom from predators, relatively stable water temperatures, and hereditary domestication. He also outlined a program of investigation for determining which conditions in a hatchery are responsible for the inferiority of hatchery trout.

Schuck's program of investigation is adequate, except that it includes no investigation of the environmental factors which may affect the embryonic development of trout; the object of my research over a period of years has been to fill this gap.

PLAN OF PRESENT RESEARCH

Laboratory and hatchery investigations.—Experiments in a controlled stream can give an approximate answer to the question of survival of fry to maturity. Factors influencing early development can best be studied in the laboratory or the hatchery, and it is with this latter phase this preliminary report deals.

PREVIOUS OBSERVATIONS

Skeletal characteristics.—Mottley (1934, 1937) showed first, that there was a direct correlation between the number of vertebrae and the length of the fish; second, that in rainbow trout the number of vertebrae differs in hatchery-reared and wild fishes (this confirms Day's, 1887, observations on brook trout of North America); and third, that the number of vertebrae could be experimentally modified by hatching the eggs at different temperatures, that the modification takes place during a critical period of hatching and that such changes could occur in a single generation. Taning (1950) experimenting with sea trout, determined that the average number of vertebrae varied with temperature changes during the "critical period."

Growth and hardiness of alevins.—The physical superiority of fry raised in gravel was pointed out as early as 1906 by Hein in Germany. Others (Harrison, 1923; Brouwer, 1931; Robertson, 1936; and Vibert, 1949) have confirmed these observations.

We do not know to what conditions the physical advantage of naturally reared fry may be traced. Possible contributing causes are dissolved salt content in natural waters, solar radiation, vitamin-rich bacteria absorbed directly, or by feeding on the larvae of aquatic invertebrates (Ivlev, 1945; Ward, 1938).

MATERIALS AND METHODS

On December 29, 1950, a mating of a single pair of salmon was made. The fertilized eggs were divided into 5 lots (No. 7 to 11) and placed for hatching as follows:

- Lot No. 7—in hatchery trough, in partial darkness ¹
- Lot No. 8—in hatchery trough, in total darkness ¹
- Lot No. 9—in gray gravel, outside, in daylight ¹
- Lot No. 10—in gray gravel, in hatchery trough, in partial darkness
- No. No. 11—in gray gravel, in hatchery trough, in total darkness

On January 2, 1951, a second pair of salmon was mated, and the fertilized eggs placed to hatch under an identical set of conditions (Lot 19 to 23).

On April 13, 1951, before the fry had started to feed, a sample of about 120 was taken from each lot and fixed in a 5-percent solution of neutralized formalin, in preparation for vertebral counts. Water temperatures in

¹ Partial darkness—hatchery troughs covered with semiopaque cloth. Total darkness—hatchery troughs covered with wooden covers to admit no light. Daylight—normal outside conditions of illumination.

the hatchery ranged from 7.5° to 8.0° C., and at the time of fixation the fry from the first series (Nos. 7 to 11) had developed for 800 day-degrees, and those from the second series (Nos. 19 to 23) for 770 day-degrees. After complete fixation in formalin the fry were processed according to the alizarine-dye treatment described by Taning (1944).

VERTEBRAL COUNTS IN THE VARIOUS LOTS OF FRY

Results of vertebral counts, made under a microscope, are presented in Figure 1. For Lots No. 20 and 22 no results are given because in the attempt to obtain more intensive staining so as to permit better photomicrographs, the length of time in the alizarine bath was increased, and the fry were so burned by the potassium as to be useless. The effect of two environmental conditions is illustrated in the diagram (Fig. 1), namely, gravel cover and solar radiation. Lots 9 and 21 were reared under normal conditions, *i.e.*, outside of the hatchery, under gravel, and in full daylight.

If we compare results from No. 9 and No. 11 we note: first, that total darkness (No. 11) caused the average number of vertebrae to drop from 59.91 ± 0.16 to 59.01 ± 0.19 , a statistically significant difference; second, that the number of completely abnormal vertebrae increases under total darkness; and third, that total darkness increases the variability in the number of vertebrae. Results obtained from Lots 21 and 23 confirm the above observations, particularly the last one.

Comparison of Lot 10 with Lots 9 and 11 shows that partial darkness gives a greater average number of vertebrae than total darkness or full daylight.

When Lot 11 is compared with Lot 8 we find that the elimination of gravel cover has brought about a significant rise in the average number of vertebrae (59.01 ± 0.19 to 59.98 ± 0.15). Abnormal vertebrae were not in evidence.

Comparison of Lot 7 with Lot 8 again reveals that partial darkness produced a larger average number of vertebrae than did total darkness.

Fry raised under gravel (Nos. 9, 10, 11) were 15-percent heavier than those raised without gravel (Nos. 7, 8). They also were better developed, and more pigmented.

Vertebral malformations illustrated in Figure 2 were numerous among fry from Lots 11 and 23. Nevertheless, fry hatched under gravel in total darkness were heavier and had fewer vertebrae than those hatched in complete darkness but without gravel cover.

In this series of experiments if the effect of light had not been separately evaluated, we would have assumed that the average number of vertebrae was approximately the same for hatchery-reared fry as for fry hatched under gravel in sunlight. Results warrant the following conclusions: first, the average number of vertebrae may be significantly influenced by solar radiation and by gravel cover, and that the separate effects of these two conditions tend to obscure one another; second, a combination of gravel cover and total darkness may produce numerous vertebral malformations; third, fry hatched under gravel are better developed, more pigmented, and

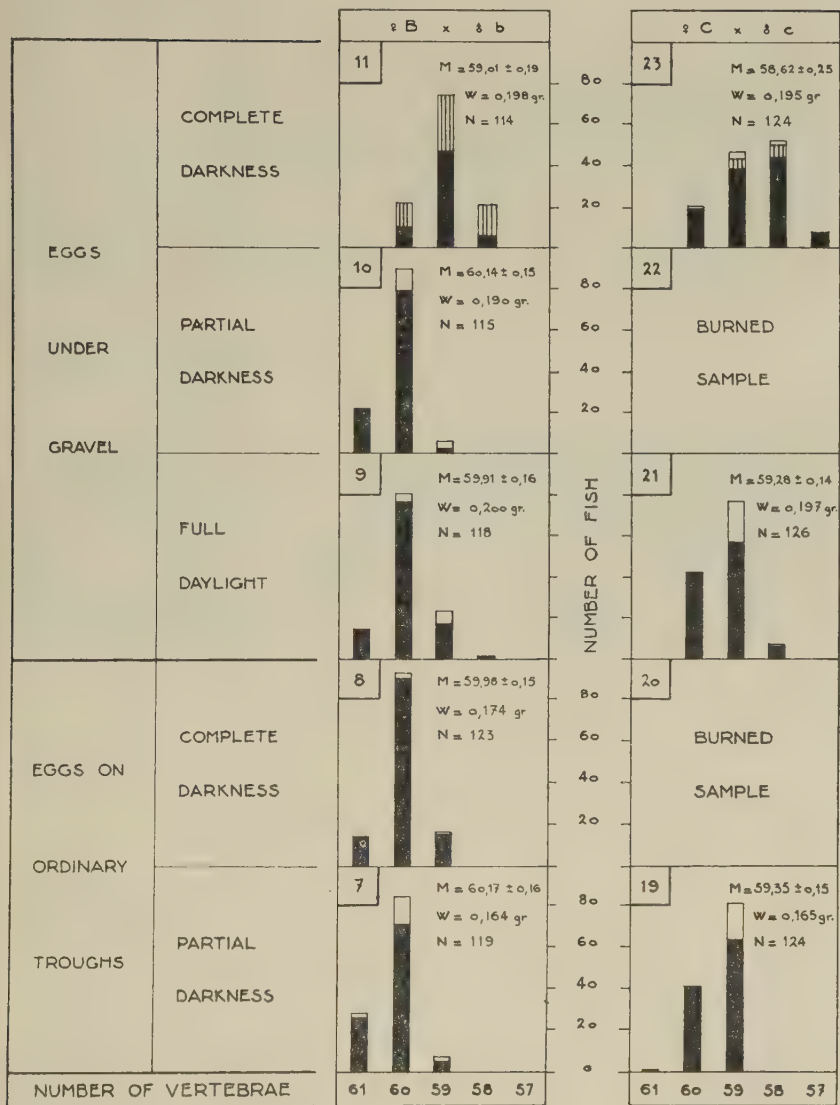


FIGURE 1.—Influence of sun radiation on the average number of salmon vertebrae. Black—normal vertebrae; white—probably anastomosis of two vertebrae, however, counted as a single vertebrae; lined—completely abnormal vertebrae; N—number of fry in each sample; M—average number of vertebrae; W—average weight.

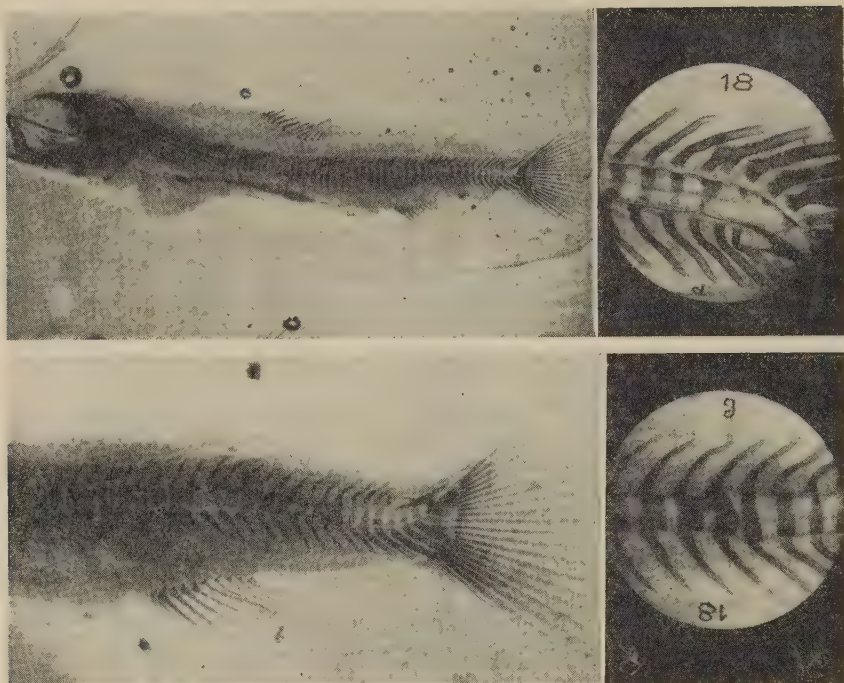


FIGURE 2.—Salmon vertebrae. Top left: normal vertebrae. Top right: probably anastomosis of two vertebrae. Lower: completely abnormal vertebrae (always in the same place of the vertebral column).

15 percent heavier than hatchery-reared fry; and fourth, mortality at time of yolk sac resorption was identical for both lots.

MORTALITY DURING EMBRYONIC DEVELOPMENT

High mortality, caused by blue-sac disease or torsion of the vertebral column, was described by Hobbs (1937) as occurring in hatcheries supplied by artesian water. He also stated that such mortality did not exist among naturally hatched fry, or fry reared in Kashmir boxes placed in a river. Vibert (1949) gave an account of an experiment where mortality caused by blue-sac disease was 52 percent in alevins hatched under gravel compared with 95 percent for alevins reared in hatchery troughs. The following experiment was performed to test these earlier observations of Hobbs and Vibert.

On December 22, 1951, brown trout eggs in a green condition were divided into two lots, and the first lot (No. 1) was placed in a hatchery trough, the second lot (No. 2) in Vibert boxes under gravel in a small creek. On January 31, 1952, eggs from each lot were examined and mortality in each lot of eggs was found to be about 20 percent. Remaining

eggs from Lot No. 1 were divided between two hatchery troughs, 3,000 to 3,400 in each. A third trough received 3,000 to 3,400 eggs from Lot No. 2. However, gravel was added to the third trough (with the eggs from Lot No. 2) so as to cover one fourth of its area. Eggs in the various troughs started to hatch on February 5, 1952. In early March, when the hatchery was being supplied by melting snow water, blue-sac disease broke out among the alevins in the first two troughs (Lot. 1) and mortality soon reached 100 percent. On April 15 fry from the third trough (Lot No. 2) were sorted out of the gravel and counted. There remained 1,591 fry, indicating a mortality of 47 to 53 percent. During the course of the experiment it was observed that fry which came out of the gravel, either on the downstream or upstream side, suffered more from the effects of snow water than those remaining under the gravel. The experiment should be repeated under more carefully controlled conditions

VULNERABILITY TO PREDATION

An experiment designed to test vulnerability to predation was performed at the Bidarray Hatchery, Basses Pyrénées, France.

On September 12, 1950, two circular ponds were each stocked with 100 minnows (*Phoxinus laevis*), 40 crayfish (*Astacus astacus*) and 3 eels (*Anguilla anguilla*). In addition they received:

Pond 1.—100 unmarked rainbow trout fingerlings which had been reared under normal hatchery conditions and 100 hatchery-reared rainbow trout fingerlings marked by the removal of the dorsal fin.

Pond 2.—100 fingerling rainbow trout, marked by the removal of the dorsal fin, and reared under gravel, and 100 unmarked, hatchery-reared rainbow trout fingerlings.

Besides the various animals stocked in each pond a few heaps of stones were added to the pond bottoms as refuges for the prey animals (trout, minnows, crayfish).

Animals remaining in the ponds were counted on November 9 with the following results:

Pond 1.—85 minnows, 14 crayfish, 25 unmarked trout, 11 marked trout, and 3 eels.

Pond 2.—98 minnows, 24 crayfish, 34 unmarked trout, 32 marked trout, and 3 eels.

The experiment justifies these conclusions: first, that eels preyed most heavily upon rainbow trout fingerlings, crayfish, and minnows in that order; second, survival among unmarked trout was more than double the survival of dorsal-clipped trout, confirming Ricker's (1949) observations; and third, that in this experiment fingerlings hatched under gravel were far less vulnerable to predation by eels than those raised under usual hatchery conditions.

CONCLUSION

This preliminary study indicates that the skeletal characteristics, growth, survival, and mortality, and vulnerability to predation of salmon and trout may all be directly influenced by certain environmental conditions such as light, and gravel cover, during early development. It is possible that these same conditions affect the success of artificial restocking, and therefore merit additional study.

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GROWTH AND HABITS OF THE REDEYE BASS

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ABSTRACT

A study of the redeye bass, *Micropterus coosae* Hubbs and Bailey, was conducted on Sheed's Creek in southeastern Tennessee during the years 1950 through 1953. This fish is common in Georgia and Alabama and also occurs in several small streams in Tennessee. The redeye bass is primarily a fish of small upland streams and is seldom found in lakes or ponds. In comparison with other black basses, the redeye bass has an average life span, grows slowly, and is relatively slender. Of the 6,363 redeye bass scales examined 82 percent were regenerated. This occurrence of scale regeneration was higher than in 13 other species of fish in eastern Tennessee streams. This report on the redeye bass includes information on the standard length-total length relationship, length-weight relationship, growth rate, parasites, food habits, spawning habits, fecundity, maturity, distribution, migration, and angling importance. The redeye bass has been propagated successfully in Tennessee hatchery ponds and has been introduced experimentally into 10 small streams of middle Tennessee that have proven to be unsuitable for either warm-water game fish or trout.

INTRODUCTION

The redeye bass, a common game fish in the streams of several southeastern states, has not been acknowledged as an important game fish, nor has it received the attention it deserves. The fish's small size and limited distribution have minimized its importance in fish-management programs.

DESCRIPTION

A beautiful fish in every respect, the redeye bass has color characteristics not found in other basses. The eyes and fins are a brick red, and the deep bronze back changes to a greenish or purplish cast, depending upon the habitat. The transverse flexuous bands on the sides and the opercular and basal caudal spots are indistinct on fish of all sizes. The young of this species can be distinguished from the other basses by the absence of the subterminal black band across the caudal lobes and the red coloration of the fins.

The redeye bass has a deeper caudal peduncle than the other basses. Seventy-one percent of 69 redeye bass examined (King and Parsons, 1951) had glossohyal teeth on the tongue. This percentage is considerably larger than that in the smallmouth bass group and somewhat less than in the spotted bass group.

The redeye bass has often been mistaken for the smallmouth bass,

Micropterus d. dolomieu Lacépède, whose appearance it most resembles. However, taxinomically the fish is related more closely to the spotted bass. The smallmouth bass does not occur naturally within the native range of the redeye and Alabama spotted bass, *Micropterus punctulatus henshalli* Hubbs and Bailey. Prominent color differences distinguish the redeye bass from the spotted bass.

DISTRIBUTION

The known distribution of the redeye bass includes Alabama, Georgia, and Tennessee, but the fish may also occur in Florida, South Carolina, and North Carolina. Hubbs and Bailey (1940) examined one specimen from the Savannah River which rises in North Carolina and separates Georgia and South Carolina. However, other fishery investigators have found no redeye bass in this drainage. One *Micropterus* specimen examined from the Apalachicola River System in Jackson County, Florida, appeared to be similar to the redeye bass, but was not positively identified (Hubbs and Bailey, 1940). Redeye bass are known to occur in the Chatahoochee River, a tributary to the Apalachicola River.

In Alabama, the redeye bass occurs principally in the Coosa-Tallapoosa-Alabama River system (Fowler, 1945). Its occurrence in Georgia includes the Alabama River system, and Chatahoochee, Oconee, and Savannah Rivers, all of which flow separately either into the Gulf of Mexico or Atlantic Ocean. Sheed's Creek and Cohutta Creek, the only two streams in Tennessee in which this fish occurs naturally, are part of the Alabama River system.

Most of the present study of the redeye bass was done on Sheed's Creek in Polk County, Tennessee. Sheed's Creek is a small mountain stream about 6 miles long, with a maximum temperature of near 73° F., and a pH near 7.0. The minimum flow is less than 1 cubic foot per second and the pools are small and shallow, usually less than 2 feet deep, with fair fish cover. The stream bed is mostly sand in the lower portions and rocky near the headwaters. Sheed's Creek flows into the Jacks River at the Georgia-Tennessee line, and the Jacks River flows into the Conasauga River approximately 100 yards downstream. Sheed's Creek is the smallest known stream in Tennessee that has a fishable bass population (King and Parsons, 1951).

The redeye bass is primarily a species of small upland streams. The fish is adapted particularly to streams that are too cold for other warm-water fishes and generally too warm for trout. Several stocked rainbow trout were taken in the Sheed's Creek samples. A good series of redeye bass was observed in North Prong of Sheed's Creek which nearly dries up in the summer, and any pool that offered depth or cover contained several redeye bass. The only other species of fish taken from North Prong was the creek chub, *Semotilus a. atromaculatus* (Mitchill), which rarely occurs in Sheed's Creek proper.

More than 10 years ago redeye bass were stocked in Sylco Creek, a small stream of the Tennessee River system on the opposite side of the mountain

from Sheed's Creek. Several fish samples obtained by the use of cresol in this stream in 1950 and 1952 indicated two distinct fish populations. The lower portion of Sylco Creek was populated with smallmouth bass and rock bass, *Ambloplites r. rupestris* (Rafinesque), and the upper reaches with redeye bass. Practically no distributional overlap existed between these two species in the stream. The redeye bass has not migrated from Sylco Creek as far as is known.

Cohutta Creek, a small, turbid, lowland stream flowing from Bradley County, Tennessee, into Georgia and the Conasauga River, was sampled in the spring of 1952. Several redeye bass were taken from the stream but these fish were not as abundant as the largemouth bass, *Micropterus salmoides* (Lacépède).

In the Alabama River system the redeye bass is closely associated with the Alabama spotted bass and the southern rock bass, *Ambloplites ariommus* Viosca. Except for the Alabama River system, the redeye bass apparently is the only *Micropterus* species in most of the streams in Alabama and Georgia.

Several fish samples taken in Jacks River in the Conasauga River near Sheed's Creek were dominated by the redeye bass. Although the spotted bass was common in the area, none has been found in Sheed's Creek. Several adult rock bass and longear sunfish, *Lepomis m. megalotus* (Rafinesque) appeared in the Sheed's Creek samples, but no young were observed.

MATERIAL AND METHODS

Angling and introductions of cresol and rotenone were used to collect samples of the redeye bass. The metric system was followed in making measurements. The conversion factor for standard length to total length is 1.21 for the redeye bass (based upon 157 specimens ranging from 3.0 to 10.6 inches, total length).

The age was determined by counting the number of annuli on the scales with the aid of a microprojector. Fish which had no annuli were placed in age-group 0; older age-groups were designated by roman numerals, corresponding to the number of annuli.

Use of the scale method to determine the age of the redeye bass is justified by the following observations:

1. Fish known to be young-of-the-year had no annuli on the scales.
2. The number of annuli increased with the size of the fish.
3. The distance between the last annulus and the anterior edge of the scale increased throughout the growing season.
4. The calculated growth was similar for fish of identical age groups in the same or different year's collections.

LENGTH-WEIGHT RELATIONSHIP

The mathematical relationship between the standard length in millimeters (L) and the weight in grams (W) of the Sheed's Creek redeye bass can be described by the formula:

$$\log W = -4.74898 + 3.03588 \log L.$$

For the derivation of the length-weight equation the 1950 and 1951 data were combined. The actual and estimated weights indicate a good fit (Table 1). The relative plumpness of the fish may be represented by the coefficient of condition, K , computed by means of the formula:

$$K = \frac{W \times 10^5}{L^3}. \text{ The average } K \text{ for the Sheed's Creek redeye bass is 2.11}$$

(Table 1). The value of K followed no distinct trend with increase in the size of fish; the small fish were approximately as robust as the large ones. This lack of trend was to be anticipated since the weight increased so nearly as the cube of the length (slope of 3.03588 in the length-weight equation. Comparisons of the K of the redeye bass with other black basses indicate that the redeye bass are usually more slender (Carlander 1951).

TABLE 1.—Length-weight relationship of redeye bass from Sheed's Creek, 1950-1952¹

Average standard length (millimeters)	Total length (inches)	Weight (grams)		Calculated weight ² (grams)	Average K^3	Number of fish
		Average	Range			
66	3.2	6	4- 9	6	2.12	5
74	3.6	8	8- 10	8	2.08	5
83	4.0	11	7- 14	12	1.88	9
93	4.4	17	11- 20	17	2.14	11
103	5.0	21	17- 25	23	1.98	7
115	5.5	32	26- 38	32	2.12	9
124	5.9	42	38- 50	40	2.20	4
133	6.3	51	42- 58	50	2.15	11
143	6.8	64	59- 74	62	2.16	8
155	7.4	80	63-102	80	2.11	19
165	7.9	96	79-112	96	2.08	16
175	8.4	118	104-142	115	2.26	14
183	8.7	135	122-150	132	2.20	13
193	9.2	160	149-188	155	2.12	14
206	9.8	184	166-202	189	2.16	5
215	10.2	208	179-236	218	2.10	3
223	10.6	228	.....	240	2.07	1

¹ 1950—86 fish, 1951—31 fish, 1952—40 fish

² From length-weight equation given in text

³ Grand average K , 2.11 (range, 1.60-2.60)

SCALE REGENERATION

A high percentage (82 percent) of the redeye bass scales were regenerated (Table 2) and the percentage of regenerated scales increased with increase in age. There is a possibility of some error in age-groups 0 and I because of the difficulty of distinguishing between regenerated areas and irregular focus formation. However, all scales that could not be clearly identified in this respect were classified as non-regenerated. Examination of all the scales of several specimens of redeye revealed no pattern of regeneration. The scales on all parts of the fish's body appeared equally subject to regeneration.

The occurrence of such a high percentage of regenerated scales creates

TABLE 2.—Scale regeneration in the different age groups of the redeye bass

Age group	Number of fish	Number of scales examined	Percentage regenerated	Age group	Number of fish	Number of scales examined	Percentage regenerated
0.....	11	185	42	VII.....	13	703	95
I.....	15	434	51	VIII.....	4	155	86
II.....	15	1,247	69	IX.....	2	230	91
III.....	5	344	79	Not aged.....	4	17	100
IV.....	16	943	85				
V.....	12	477	90				
VI.....	20	1,292	92	Total all fish.....	118	6,363	82

certain investigational difficulties. Large numbers of scales necessarily must be taken from each fish to insure an adequate number of readable samples. Usually 50 scales from each redeye bass were sufficient for general sampling. Such large scale samples make difficult, however, the satisfactory determination of the body-scale relationship since size of scale varies according to location on the body. The body-scale relationship of the redeye bass in this study could not be determined for that reason. Moreover, unless considerable care is taken, counts of annuli on the scales of the redeye bass may be subject to significant error.

The degree of scale regeneration of the redeye is considerably greater than in other species in eastern Tennessee streams (Table 3). The species with ctenoid scales are generally more subject to scale regeneration than those with cycloid scales.

TABLE 3.—Scale regeneration in certain species from streams in eastern Tennessee

Species	Number of fish	Number of scales examined	Percentage of scales regenerated
Longear sunfish.....	3	57	67
Northern rock bass ¹	17	264	65
Smallmouth bass ²	22	692	60
White sucker ³	7	343	56
Spotted bass ⁴	8	185	54
Southern rock bass.....	10	175	50
Bluegill ⁵	7	101	50
Largemouth bass.....	2	13	46
Hog sucker ⁶	33	1,034	44
Carp ⁷	3	28	39
Golden redbhorse ⁸	19	305	35
Common shiner ⁹	8	88	25
Muskellunge ¹⁰	12	197	4

¹ *Ambloplites r. rupestris* Rafinesque. ² *Micropterus d. dolomieu* Lacepede. ³ *Catostomus c. commersoni* (Lacepede). ⁴ *Micropterus p. punctulatus* (Rafinesque). ⁵ *Lepomis macrochirus* Rafinesque. ⁶ *Hypentelium nigricans* (Le Sueur). ⁷ *Cyprinus carpio* Linnaeus. ⁸ *Moxostoma erythrum* (Rafinesque). ⁹ *Notropis cornutus chrysocephalus* (Rafinesque). ¹⁰ *Esox masquinongy ohioensis* Kirtland.

ANNULUS FORMATION

Scales were examined from several redeye bass taken during the months May through November. The scales taken from fish on May 15, 1952,

showed evidence of annulus formation and by early June 1952, the annuli were clearly evident.

AGE AND GROWTH

The growth rate of the redeye bass compared with other game fish is particularly slow (Table 4). The growth is greatest the first year and gradually decreases as the fish become older. On an average, a 10-year-old redeye bass grows about 1 inch in length each year. Compared with the other black basses (Carlander, 1951), the redeye bass has average longevity, but a much slower growth rate.

TABLE 4.—*Calculated growth of the redeye bass, Sheed's Creek, 1950 and 1951*

Number of fish	Age group	Calculated standard length (millimeters) at end of year									
		1	2	3	4	5	6	7	8	9	10
15	I	53	..	...	...	...	...	...	...	...	...
15	II	42	80	...	...	...	...	...	...	...	...
5	III	44	78	108	...	...	...	...	...	...	...
15	IV	36	68	97	122	...	...	...	...	...	...
14	V	37	63	92	116	137	...	...	...	...	...
17	VI	37	66	89	114	141	157	...	...	...	...
11	VII	38	68	98	125	148	165	178	...	...	...
5	VIII	37	60	92	110	130	155	173	183	...	...
2	IX	39	68	94	112	127	142	155	164	170	...
1	X	31	61	85	104	123	150	167	180	196	211
Average standard length.....		40	69	94	118	140	158	174	178	179	211
Average annual increment.....		40	31	27	25	24	18	15	9	10	15
Sum of increments ...		40	71	98	123	147	165	180	189	199	214
Sum of increments (Total length in inches).....		1.9	3.4	4.7	5.9	7.0	7.9	8.6	9.0	9.5	10.2

In the fall the observed lengths of the 0-group fish agreed satisfactorily with the lengths calculated by the scale method. The total lengths of young-of-the-year redeye bass from Sheed's Creek averaged 54 millimeters in November 1951. In mid-June, 1953, 30 young fish, averaging 23 millimeters, total length (range of 15–32 millimeters) were taken.

According to other fishery workers the redeye bass in Sheed's Creek represent a normal population as far as size is concerned. The largest redeye bass on record, approximately 2 pounds, was reared in a private hatchery pond (personal correspondence). A ½-pound redeye bass would be considered a good catch by most fishermen.

FOOD HABITS

No comprehensive study was made of the food of the redeye bass although enough stomachs were examined to give some indication of their food habits (Table 5). Insects taken from the surface of the water appear to be the most common food.

TABLE 5.—Frequency of food organisms in 56 redeye bass stomachs, Sneed's Creek May and August, 1950 and 1952

Item	Frequency of occurrence	Item	Frequency of occurrence
Empty.....	14	Crayfish.....	3
Adult insects.....	31	Fish eggs.....	1
Chironomid larvae and pupae.....	10	Salamander.....	1
Fish remains.....	4	Caddisfly case.....	1

DISEASES AND PARASITES

By gross examination the redeye bass examined appeared to be relatively free from diseases and parasites. Several fish had moderate infestations of parasitic nematodes in the intestine and strigeid larve (black grubs) on the external surface. No larval or adult tapeworms were found in the body cavities although these parasites are usually common in the centrachids of Tennessee.

REDEYE BASS IN PONDS

To judge from its natural habitat, and from experiences with the species in ponds and lakes, the redeye bass is not suitable for standing waters. The Federal fish hatchery at Cohutta, Georgia, and the Amakanata Hatchery, a private hatchery at Calhoun, Georgia, reared and stocked this fish in form ponds and lakes for several years during the 1940's. In recent years these hatcheries have discontinued production of the redeye bass. Apparently the fish were too small to satisfy the pond owners and could neither compete against other predators nor suppress the sunfish populations.

A 20- acre lake impounded in 1948 in the Conasauga River drainage in Hamilton County, Tennessee, produced redeye bass from the native stock of the small spring creek that was impounded. During the second year of impoundment largemouth bass were introduced and the redeye bass is now rarely taken from the pond.

In 1950, the Etowah River in Georgia was impounded to form the Allatoona Reservoir. A pre-impoundment survey indicated the fish population to contain 5 percent redeye bass by number and 13 percent spotted bass (Hueske).¹ During the first year of impoundment a sample obtained by use of rotenone contained 29 percent redeye bass and 14 percent spotted bass. Most of these fish apparently were young-of-the-year fish. A creel census taken in 1950 by the Fish and Wildlife Service revealed that the redeye bass constituted only 2 percent of the catch. In 1951 these fish represented an insignificant portion of the fish catch and most of them were taken at the headwaters of the reservoir (Franz).² It is generally recognized that stream fish often expand rapidly in new impoundments only to be

¹ Hueske, Edward E. 1950. Fish reproduction, growth, and fishing success during the first season in Allatoona Reservoir. A report to the U. S. Department of Interior. Fish and Wildlife Service, Atlanta, Georgia, 8 pp. [Mimeographed]

² Franz, Robert K. 1952. A progress report of fisheries investigations. 1951. Allatoona Reservoir, Georgia. A report to the U. S. Department of Interior. Fish and Wildlife Service, Atlanta, Georgia. 18 pp. [Mimeographed]

crowded out as the competition increases and the fish population becomes more stabilized. Apparently such is true with the redeye bass.

REPRODUCTION IN HATCHERIES

The propagation of redeye bass in hatcheries has met with variable success, but generally enough fish can be raised to supply fish for introductory stockings in streams. In May 1952 the author placed 25 adult redeye bass in a cold, fertilized hatchery pond. When the pond was drained on September 20 of the same year 13 adult fish remained. Present also were 311 young-of-the-year fish ranging from 2.0 to 5.9 inches in total length. The average length was 4.4 inches, an excellent size for stocking. In 1953, several thousand more young redeye bass were hatched.

The 25 redeye bass originally stocked in the pond had an average K of 2.10 (range 1.60-2.40) and the 13 recovered had a K of 2.30 (range 2.08-2.60). All of these fish appeared extremely healthy. The young redeye bass had an average K of 2.16 (range 1.77-2.38).

FECUNDITY AND MATURITY

The gonads of redeye bass from Sheed's Creek were examined on May 15 (35 fish) and July 2, 1952 (25 fish). The adult females taken in May were plump but none was ripe. In July, only two of the five adult females appeared to have spawned and the five adult males still had well developed gonads. The water temperature in Sheed's Creek ranged from 62°-69° F. between the above dates.

The smallest "mature" female taken was 120 millimeters (4.7 inches) long (total length), weighed 16 grams (0.56 ounce), and was 3 years old. Some question may exist as to the state of maturity of this fish since it is doubtful whether it would have spawned in 1952. The smallest mature male, taken in July, was 122 millimeters (4.8 inches) long (total length), weighed 19 grams (0.63 ounce), and was 4 years old. Of the 60 redeye bass examined, most that were larger than the aforesaid fish were mature, and all smaller fish were immature. Several of the streams stocked experimentally with redeye bass in 1952 were examined in June 1953. Several of the stocked male and female redeye bass recovered as yearlings were over 6 inches in length and sexually mature.

In Sheed's Creek, the redeye bass spawned during late May, June and early July in both 1952 and 1953. Possibly some spawning occurred even later. Observations made during the spawning season in 1953 disclosed nests similar in most respects to those of the smallmouth bass. Shallow depressions in coarse gravel (1/2-inch diameter) were observed in the eddy water at the head of several pools. The newly hatched young remained in schools for only a short time.

Egg counts were made from two redeye bass in May, 1952. One female 145 millimeters (5.7 inches) in total length, 35 grams weighing (1.24 ounces), and 5 years of age contained 2,084 eggs, and another, 205 millimeters (8.1 inches) in total length, weighing 98 grams (3.46 ounces) and of unknown age, contained 2,334 eggs by count.

MIGRATION

Observations on movements of redeye bass were made on Sheed's Creek during the fall of 1952. On October 15 the first heavy frost occurred and the water temperature lowered considerably. At this time redeye bass were observed to be moving downstream. As the cold weather persisted most of the fish had moved into the Jacks River by late October, and by November 2, no redeye bass were observed in Sheed's Creek. The absence of fish was substantiated by the survey of November 6. Residents of the area stated that this general downstream movement occurred every fall.

On November 6, 1952, seines, cresol, and rotenone were used to sample the fish populations in the Conasauga and Jacks Rivers in Georgia and Sheed's Creek in Tennessee. Rotenone treatment of 0.6 mile of the Conasauga River produced only one 4-inch redeye bass and 4-inch Alabama spotted bass. Other fish taken included a few young channel catfish and other small non-game fish. Conditions for observation were excellent, the water temperature was 43° F., and the chemical was effective to the Conasauga River's confluence with the Jack's River. Seines and cresol produced similar results in the same and other parts of the two streams. The sampling in Conasauga and Jacks Rivers indicated that the downstream movement also occurred in these two sizeable streams. Comparison of the fall samples with collections made during the summers of 1952 and 1953 suggested that southern rock bass, Alabama spotted bass, longear sunfish, channel catfish, and redhorse suckers migrated as well as the redeye bass.

Further investigations on Sheed's Creek on March 1, 1953, yielded evidence that the redeye bass were moving upstream again in appreciable numbers but that the migrants consisted mostly of adult fish. By April 1, young fish had arrived and the redeye bass population appeared to be at its summer normal.

The tenacity of the redeye bass in their migration was proven by their movement over a 6-foot vertical rock dam on Sheed's Creek. On such a small stream this dam might be expected to offer an insurmountable barrier to migrating fish. Yet the absence of redeye bass above the dam in winter and their abundance in the same waters in summer proved that they had passed the dam. This upstream migration could have been accomplished only during flash floods. Downstream migration in the fall could have been accomplished only if the fish swam on their sides through a crevice on top of the dam. Redeye bass were the only fish species other than minnows found above the dam.

It was not determined whether the same individuals turned to Sheed's Creek each spring. Neither do we know the limits of the downstream movement. The rigorous migrational activities of the redeye bass may account partly for the fish's high degree of scale regeneration.

ANGLING VALUE AND MANAGEMENT

The redeye bass is considered by most fishermen to be a desirable addition to the creel. The fish is "scrappy," colorful, and highly palatable. The author has taken redeye bass readily with artificial lures in larger streams,

but they are wary and difficult to catch in small, clear streams such as Sheed's Creek. Live bait proves most successful in the smaller streams, and the fish will test the patience and stealth of any fisherman.

To the biologist and fisherman alike the redeye bass may be considered as the "brook trout of the warm-water game fish." The fish is much like the brook trout in size, habitat-preference, food and feeding habits, desirability, and gameness. The admirable qualities of the redeye bass are not offset by its small stature.

The redeye bass is of interest to the Tennessee Game and Fish Commission because of the presence of several hundred miles of streams in middle and eastern Tennessee that are marginal to both warm- and cold-water game fish. These streams usually contain several small adult small-mouth bass or rock bass but are generally considered worthless by the fisherman. The adaptability of the redeye bass to these waters had been demonstrated.

In the summers of 1952 and 1953 the Tennessee Game and Fish Commission successfully reared several thousand young redeye bass which were experimentally stocked in 10 spring-fed streams on the Highland Rim area of Eastern Tennessee that have proved, in the past, to be unsuitable for trout. If the redeye bass can successfully provide fishing in these and similar streams, these fish will be important to fish management in Tennessee. It is not expected that the redeye bass will compete greatly with the smallmouth bass or trout where either is doing well. Studies of the results of the experimental stocking will determine the future status of this fish in Tennessee.

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FISHERY RESEARCH AT MID-CENTURY ¹

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ABSTRACT

In North America fishery research is approached by almost as many administrative avenues as there are agencies engaged in it. Between these agencies differences exist in needs, plans, staff organization, methods of enlisting public support, and in the application of research findings. This situation is desirable. In the comparative infancy of fishery science any tendency toward development of stereotyped doctrine should be deplored. Originality and eclecticism should be encouraged, both in training institutions and in research and administrative bodies. An objective review of apparent successes and failures to date, however, may prove of value in illuminating pitfalls and in pointing out procedures which have resulted in progress. From this review profitable methods and promising areas for future activity may be inferred by the reader.

Fishery research in North America, particularly on inland waters and with the objective of sustained or improved production of game and food fishes, came into being gradually. Based on the early work of naturalists, ichthyologists and limnologists and on the arts and crafts of the fish culturist, fishery research can hardly be said to have had a definite time or place of origin. By the end of World War I, however, when the eight-hour day, wide ownership of automobiles, and a rapidly growing system of highways resulted in an explosive increase in angling pressures, there arose a general demand for a scientific approach to the problems these pressures created. The few existing research programs were expanded and new ones arose in many places, their character determined largely by the

¹ The authors were invited to present papers at a symposium on the organization, popularization and application of fishery research. Discovering that their prepared papers contained much duplication of ideas and material, they abandoned their manuscripts and conducted the symposium as a round-table discussion followed by audience participation. In this joint paper they summarize their individual and collective views.

knowledge, judgment and imagination of their creators. It is not surprising, therefore, that in the past three decades almost as many types of organizational plans for fishery research have arisen as there are agencies involved.

Whether or not we have progressed far enough and gained enough experience to permit formulation of dogmatic principles for planning, staffing, directing and selling a fishery research program seems doubtful. A body of trial and error experience has accumulated, however, and an appraisal of some of these approaches may be profitable.

Because of the nature of its support, fishery research has always been denied the security of personnel and programs widely enjoyed in other research fields. This situation is particularly true of investigations in the sport fisheries which, being almost invariably in public waters, are administered by and for the public through governmental agencies established for the purpose. Experience has shown that the license-buying public is prone, again unlike other research fields, to peer constantly over the shoulders of its fishery researchers, and that it does not hesitate to urge its own often emotional ideas in preference to the objective findings of trained scientists. For this reason fishery research cannot be planned, or its results implemented by management, without operation of a continuous and concurrent program of public education to insure understanding of methods, aims and objectives. If understanding is inadequate the program will falter. If understanding is lost the program may be discarded *in toto* and the baby thrown out with the bath water.

A host of prickly questions must be answered by the administrator of a research program before a wheel is turned. Will he undertake fundamental or applied research (if he is able to distinguish between these as separate approaches)? Will he recruit a sizeable group of mediocre workers at low salaries, with incident rapid turnover, or engage a smaller staff of outstanding men at salaries adequate to insure their retention? Is his working budget reasonably predictable, or is it subject to annual feast-or-famine whims of legislators? Will the men who conduct research be charged also with its translation into management? Should he spread his funds and personnel thin and attempt to cover a wide range of needs, or try to concentrate on bringing to fruition a few studies at a time while neglecting others? Can he protect his staff from political harassment?

An examination of the record shows that these questions have been answered in almost as many ways as places. And evidence of present soul-searching exists in almost every quarter, indicating that few administrators feel they have found the true and unmistakable pathway to salvation.

As Kipling's poem runs,

"There are nine-and-sixty ways of composing tribal lays,

And every single one of them is right."

Certainly there is no single "right" way to organize and operate a fishery research program. Any system that works is right, even though it might be utterly wrong in other hands or another location.

At the outset, there is the question of whether or not a public conserva-

tion agency should employ only management technicians and "farm out" its research problems to colleges and universities. This view appears to be most popular with department heads and deans of colleges and universities. In some instances the plan has seemed to be workable. Among its advantages are the freedom from outside pressures and from diversion to trouble-shooting assignments enjoyed by academic workers; the ready access of such workers to adequate library facilities, and the availability of other members of the academic community as consultants; and complete freedom of the researcher to publish findings without regard for effect on any agency's "policy." There are many examples, however, to support the belief that research done by an agency's own personnel will meet with more rapid acceptance by its other employees, and be more quickly incorporated in management than will new ideas which originate with another institution.

The line between so-called basic and applied research is hard to discern, if it exists at all. It is almost equally difficult to draw a line between research and its application in management. Seldom can research findings be applied with confidence until they have been tested by a pilot-plant run—and the pilot plant often may embrace an entire state or province. A large, well supported organization may be able to afford a modest sized ivory tower for fundamental research, a separate contingent to take care of routine inventory, survey and trouble-shooting, and a trained group of fishery managers to translate research results into action. Most agencies have found it necessary to ask their trained men to serve concurrently as researchers, managers, and public relations representatives, and it is a testimony to the energy and ability of these triple-threat men that they have contributed importantly to the advancement of our field.

The role of the fishery biologist will vary widely, depending upon his employer's needs. If he has the responsibility of organizing a research project he immediately becomes something of an administrator—and there are those who feel this is almost like having the chairman of the board also serving as head of the union local.

Actually, only the most starry-eyed of biologists can indulge in the luxury of ignoring administrative problems. He must make his own case for funds and facilities, plan his program within limits of the possible, and constantly scrutinize his plan with stern conscience to be sure he is assigning priorities on the basis of reasoned need rather than personal predilection. No matter how much latitude is allowed him by his administrative superiors, he will find it advantageous to keep them apprised of the reasons why he adopted the current project, why it seems more urgent than other desirable projects, and how it fits into the picture of over-all research needs. If he is thorough and foresighted in these considerations the chances are infinitely better that his project will emerge unscathed and unmutilated by the various axe-wielding officials through whose hands it must pass.

Without question, the prosecution of the project, once it has received the green light, should be up to the biologist, without administrative inter-

ference. That is the job for which his professional training qualified him, the job he was hired to do. How he does it, how he elects to use the personnel and facilities at his disposal, is up to him. If he can do the job alone, the problem is simple. If he has assistants it is up to him to break the project down into chunks that an assistant can handle. If the training and experience of these assistants is of subprofessional level he will have to supervise their individual efforts in considerable detail. If they are competent professionals he will be wasting time if he concerns himself with detail. He will need all his time and energy to assimilate and evaluate the information they supply to him.

A good research program depends about equally on opportunity, facilities, competent personnel, and funds in reasonably predictable amount. Predictability is more important, actually, than quantity, for only when plans can be laid for several consecutive years can the research chief avoid the evils of "quickie" research. Probably there is not a man in the business who would not prefer a budget of fifty thousand dollars per year for ten years to one half a million this year and no assurance for the years to come. One of the most wasteful features of government-supported fishery research, state or federal, is alternation of feast-or-famine appropriations which lead to a build-up of staff and facilities during fat years, only to see the staff dispersed and the facilities deteriorating from disuse during the lean. Ambitious research programs conceived and initiated in a flush period and left stranded a year or two later by drastic budget cuts leave biologist and administrator alike with half-truths and vague trends, and may be worse than no research at all from the management standpoint.

No research program can be successful unless its results are incorporated in management. Vital information loses its value if it lies ignored in the files. Research results must be translated into management by administrative decision. And only the boldest administrator will depart significantly from past procedure unless he feels assured of public support.

Education—making research findings available to the public in assimilable form—is essential to management progress. Experience repeatedly has shown that it is foolhardy to undertake any marked changes in a fish management program, no matter how sound the basis for the changes, unless the public understands the reasons. Even then old ideas die slowly, and a constant stream of information through all available publicity media may be required to win support for programs based on adequate facts. A prime example is the persistence of the artificial propagation of many species of fishes in the face of literally scores of experimental demonstrations of its lack of value.

Who is to accept responsibility for education of the public in the implications of new facts established by research? Many methods have been tried, none wholly successful. The researcher himself tends to be over-cautious in releasing information, and too often cloaks his findings in obscure, dull, or just plain sloppy writing. The professional publicist can write copy people will read, but often has trouble finding out, from the researcher, just what the ideas are that he is supposed to get across.

Understandably, the most effective educational jobs have been done by the occasional biologist willing to learn how to write, and by the growing number of outdoor writers who have learned to read and comprehend technical language and reports.

Experience has shown that both administrator and general public must be kept constantly abreast of research progress. They cannot be expected to wait for the final report. On the other hand, if an account has been made of each step of research progress and its probable significance, both administrator and public stand a good chance of being ready to act without additional selling, once the investigation is completed.

In such a young and rapidly growing field as fishery research the question of what constitutes desirable professional training is constantly in the minds of employers and teachers alike. There seems to be rather general agreement that we have not yet accumulated enough "established doctrine" to warrant outlining a regular four-year college course in Fishery Biology, as is done in the older fields of Forestry or Economic Entomology, for example. For some time to come, courses of study providing a broad background in fundamental biological and physical science, and in the humanities, would seem to give a student his best undergraduate preparation, with instruction in specific fishery procedures and techniques reserved for postgraduate study and on-the-job training.

The type of practical training sometimes referred to as an "internship" is growing in favor with many administrators. Agencies which can offer summer work or part-time employment to fishery students serve both their own needs and those of the student. Agency-supported graduate assistantships have, historically, produced some of the most useful concepts and tools of our current management practice.

In summary, it would seem that future success of fishery research is contingent upon recognition, by all concerned, of the following admittedly over-simplified points:

1. Research work should be insulated from routine, "trouble-shooting," management investigations. Whether or not the two fields of activity should be wholly separated administratively is doubtful, since mutual understanding of problems by research and management personnel is most essential.
 2. Administrators must realize that adequate time will be required to produce adequate research results, and do all they can to insure against the dropping of projects prior to completion.
 3. The research program must be directed at top priority problems, and the aim must be accurate.
 4. The public must be kept constantly informed of research progress and results, in comprehensible terms.
 5. Maintenance of high standards of training and practice are bound to yield practical results in increasing quantity, and lead to public acceptance of fishery science as a recognized and useful profession.
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Part 11

Symposium

**RESEARCH ON FISH DISEASES:
A REVIEW OF PROGRESS
DURING THE PAST 10 YEARS**

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SYMPOSIUM

RESEARCH ON FISH DISEASES:

A REVIEW OF PROGRESS DURING THE PAST 10 YEARS

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INTRODUCTION

Symposia are being included in the programs of the meetings of various professional societies at an increasing rate. In some of the symposia, results of original research are presented for the first time. In others, progress is reviewed in certain fields over a certain period. In this symposium, progress made during the past decade in the study and treatment of fish diseases, is reviewed; in addition, some unpublished information is presented for the first time. Dr. Louis Wolf, in his letter commenting on this symposium, emphasized that, "We need to have all this scattered information brought together and thereby made accessible and available." Such periodic critical reviews are of great value to researchers, the public and administrators.

I do not know of a better statement of the situation with which the research workers are now confronted than the following one made by Dr. Vannevar Bush (1945), director of the Office of Scientific Research and Development during the last world war.

There is a growing mountain of research. But there is increased evidence that we are being bogged down today as specialization extends. The investigator is staggered by the findings and conclusions of thousands of other workers—conclusions which he cannot find time to grasp, much less to remember, as they appear. Yet specialization becomes increasingly necessary for progress, and the effort of bridge between disciplines is correspondingly superficial.

Professionally our methods of transmitting and reviewing the results of research are generations old and by now are totally inadequate for their purpose. If the aggregate time spent in writing scholarly works and in reading them could be evaluated, the ratio between these amounts of time might well be startling. Those who conscientiously attempt to keep abreast of current thought, even in restricted fields, by close and continuous reading might well shy away from an examination calculated to show how much of the previous month's efforts could be produced on call.

The difficulty seems to be, not so much that we publish unduly in view of the extent and variety of present-day interests, but rather that publication has been extended far beyond our present ability to make real use of the record. The summation of human experience is being expanded at a prodigious rate, and the means we use for threading through the consequent maze to the momentarily important item is the same as was used in the days of square-rigged ships.

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Realizing this pressing need for summary reviews in the field of fishery research, I suggested 2 years ago that in addition to the presentation of research papers, symposia be added as a regular feature of the programs of the meetings of the Society. I also volunteered to organize one on fish diseases for the 1952 meeting. The approval of my suggestion was too late to permit me to prepare such a symposium last year and therefore it is being presented now. So far as I know, this is the first symposium on fish diseases ever held.

If the idea of symposia and review papers appeals to the members of the Society (and I think it will) symposia on various aspects of fishery problems should be included in the program of each year's meeting but they should not replace the usual presentation of research papers. I should also suggest that symposia on the same subject, as this one on fish diseases, be repeated at intervals of about 5 years.

In the selection of the subjects and speakers for this symposium, I was motivated by the desire to have reviewed those subject matters in which either considerable progress has been made, or may be anticipated.

To assist those interested in the literature on the subject, I have selected the following six references on fish diseases which I consider as most comprehensive: Davis (1946) on diseases of trout; Schäperclaus (1941), Lyman (1949), Allison (1950) and Davis (1953) on disease of warm- and cold-water fishes; Wunder (1949) on diseases of warm-water pond fishes; and Dobie *et al.* [in press] on the diseases of minnows.

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ADVANCEMENTS IN PREVENTION AND TREATMENT OF PARASITIC DISEASES OF FISH¹

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ABSTRACT

The most recent advancement in control of external organisms causing fish disease is the pond-treatment method. It is an improvement over the hand-dipping method because fish are not killed by handling, fewer men are needed to carry it out, and the pond itself is treated along with the fish. All external parasites are controlled by a treatment with formalin (diluted to 1:4000) for an exposure of 1 hour, except *Ichthyophthirius multifiliis*, parasitic copepods, and species of *Saprolegnia*. *I. multifiliis* can be controlled by holding affected fish in swiftly running water for several weeks or by chemical treatment of the water for the duration of the life cycle of the parasite. Free-swimming larvae of the copepod *Salmincola edwardsii* can be killed by chemical added to the water; because of the parasite's long life cycle, treatment would hardly be feasible at large hatcheries. *Saprolegnia* sp. (fungus) can be killed readily by dipping fish in a 1:15,000 solution of malachite green for 10 to 30 seconds, or by introduction of the chemical into the pond for 45 minutes at a dilution of 1:180,000. Fish eggs can be kept fungus-free by semi-weekly treatments with a 1:200,000 concentration of malachite green.

Comparatively few internal parasites cause mortalities among fish. *Octomitus salmonis* can be controlled by adding 0.2-percent calomel or carbarsone to the food for 4 days. Adult tapeworms of the genus *Proteocephalus* can be purged from fish by feeding for 1 week food containing 1½- to 2-percent kamala. Fish can be protected from the eye fluke (metacercaria of *Diplostomum flexicaudum*) by killing all snails in the pond and preventing entrance of infective cercariae with the supply water.

INTRODUCTION

The control of parasitic diseases of fish is of prime importance if we are to rear fish successfully. The search for more effective methods and drugs to combat fish parasites is, as it is in human medicine, never-ending. The purpose of this paper is to bring together advancements made since about 1940 in the use of new drugs and the methods of application. With one exception, the discussion will be confined to the control of parasites found in fish hatcheries, since control of fish parasites in nature is, with present knowledge, seldom possible.

NEW METHODS OF TREATMENT

The treatment of fish for external parasites is accomplished by hand dipping and pond treatment. In the former method, fish are taken from the

¹ Contribution from the Michigan Institute for Fisheries Research.

trough or pond and dipped, a few at a time, in a solution of the chemical prescribed for the parasite present, and then returned to the trough or pond. This method has many disadvantages. Many man-hours are required to complete the treatment, weak fish are killed because of handling, and, since it is not always possible to sterilize the pond itself, fish are often returned to infested waters.

The most recent development is that of pond treatment, where chemicals are applied to the entire pond containing infested fish. In this method, fish are not killed by handling, one or two men can do the work, and the pond itself is cleared of parasites along with the fish. In cold-water-fish culture, Kingsbury and Embury (1932) applied chemicals directly to the supply water of ponds, and Fish and Burrows (1939) reported success with recirculation of chemicals through ponds. Although these procedures have definite advantages over the hand-dipping method, they are not generally used. One objection is that disinfectants do not penetrate the sediment in dirt ponds and may be neutralized by the organic matter present.

Fish (1944, 1947) described a method of prolonged treatment in a pond or trough, in which the weight of water is determined and the amount of chemical necessary for the desired dilution is added to the water. Commonly the water level is held below normal with inlet and outlet closed; less of the chemical is required and the pond or trough can be flushed more quickly after treatment. The preparation and administration of this treatment requires little labor and the procedure is well adapted to prophylactic treatments because of its simplicity. Unfortunately, however, it is not possible to employ this method in ponds where inflow and outflow of water cannot be shut off effectively.

Application of the treatment is made by spraying greatly diluted solutions of the chemicals onto the surface of trough or pond. Water sprinkling cans are satisfactory in troughs but are not suitable for large ponds. In Michigan a small power sprayer mounted on wheels has been used to advantage. The outfit consists of a 20-gallon tank, a gasoline motor, and a coil of hose. This unit is economical in that it is also used for other purposes, such as spraying weed killing compounds and certain paints.

CONTROL OF ECTOPARASITES

Most of the parasites that cause mortality among hatchery fish attack fish externally. A list of parasites commonly found follows:

Protozoa:

Costia necatrix

Trichodina sp.

Chilodon cyprini

Ichthyophthirius multifiliis

Epistylis sp.

Scyphidia tholiformis

Trematoda:

Gyrodactylus spp.

Dactylogyrus spp.

Copepoda:

Salmincola edwardsii

Fungi:

Saprolegnia spp.

With the exception of *I. multifiliis*, *S. edwardsii*, and *Saprolegnia* spp., all of these parasites can be eradicated by a 1-hour pond treatment with formalin at a dilution of 1:4,000 (Fish and Burrows, 1939; Fish 1940a, 1940b, 1947). Fish (1947) recommended that the quantity of formalin needed for the treatment be diluted about one hundred times and sprayed over the surface of the entire pond to prevent formation of "hot spots" toxic to the fish. The formalin should be sprayed into the pond within a period of 15 minutes. Since formalin is colorless, a small amount of oxalate crystals of malachite green is commonly added to the formalin in Michigan, to serve as a "tracer" and show areas of high or low concentrations. L. E. Wolf (private communication) uses a 1:1,000 dilution of formalin for 20 minutes in a trough treatment, but reported that this concentration caused a considerable mortality of rainbow trout fingerlings. Fischthal (1949) described *Epistylus* on brook trout and recommended a 1½- to 2-minute dip in a solution of salt (3 percent) and malachite green (1:15,000) to eradicate the parasite. In Michigan, we have used the formalin pond treatment to control successfully this protozoan.

Because of its more complex life history, *Ichthyophthirius multifiliis* cannot be eradicated by one treatment. Since the stage on the fish is imbedded in the flesh and cannot be reached by chemicals, control methods must be aimed at killing the free-swimming young. The easiest and least expensive control measure is to hold the fish in swiftly running water until all encysted forms have left the fish. The water current carries away the young before they can infest another fish. When this method is not practical, chemical control must be used.

Fish (1947) recommended daily pond treatment for *Ichthyophthirius* with formalin (1:5,000 for 1 hour) for 7 to 14 days. Butcher (1947) found that daily pond treatments with 2-percent salt solution for the duration of the full period of the parasitic stage were effective. Wolf (1938) reported the parasitic stage to last 4 to 5 weeks at a temperature of 52° F. At the Ballarat Fish Hatchery in Victoria, Australia, Butcher (1941, 1947) found that the life cycle of the parasite was from 14 to 16 days at water temperatures of 60° to 62° F. According to these studies, a temperature variation of 8° to 10° F. alters the length of the life cycle by about 3 weeks. Since Wolf and Butcher have shown that the length of the parasitic stage depends upon water temperature, the duration of the treatment should be judged accordingly.

Schäperclaus (1941) recommended a prolonged treatment with quinine to eliminate *Ichthyophthirius*. The chloride, sulfate, or "Chinin-Weil" may be used. He used a dilution of 1:50,000 for the length of time necessary to effect control (3 to 20 days). He also employed quinine in the same dilution to control *Costia*, *Chilodonella* and *Cyclochaeta*. He found that these three were killed in 26, 18, and 6 hours, respectively, at 15° C.

No effective method suitable for large hatcheries has yet been proposed for the eradication of the copepod, *Salmincola edwardsii*, infesting the gills of brook trout. Its tough, chitinous exoskeleton and the habit of burying its head in the flesh of the host protect the adult from chemical treatments.

The free-swimming larvae are vulnerable to chemical control, but since the adult remains on the fish for at least 2 months, chemical control would have to be in effect for that period. Exposure to strong salt solutions, and to formalin in a dilution of 1:6,000 for 1 hour kills free-swimming larvae. Undoubtedly, other effective chemicals could be found. It would hardly be feasible, however, to carry out such a program for 60 days in hatcheries as large as the average state fish hatchery. In states with a number of trout hatcheries, the problem could be solved by rearing brook trout only in those stations free of the parasite, and other species of trout at stations having a contaminated water supply. However, the cost of transporting the fish to streams widely scattered over the state might be prohibitive.

In England, Hindle (1949) effectively controlled *Argulus* on carp in aquaria by an exposure of 2 or 3 days to a 1:10,000,000 dilution of "gammexane" (gamma isomer of hexa-chloro-cyclo-hexane) called lindane in the United States. Since this chemical is insoluble in water it must be dissolved in alcohol before it is mixed with the water. Hindle used a 1-percent alcoholic solution as stock. He pointed out that with few exceptions, this treatment had been applied only to carp and that other species of fish may be less tolerant to the chemical.

The common species of fungus on fish is *Saprolegnia parasitica*. Other species of water mold may appear occasionally, but they need not be listed here since the same control measures apply to all. In the past, solutions of common salt, copper sulphate, potassium permanganate, and possibly others, were used for control, but none gave completely satisfactory results and some were dangerous to the fish. Foster and Woodbury (1936) first employed malachite green as a fungicide. Their experiments, however, involved only a special lot of trout. Although the literature contains warning that only the zinc-free salts should be employed, L. E. Wolf (private communication) reported that he always used the double zinc salt on fish and had uniformly good results. Wolf pointed out that this salt should be used with caution since direct experimental comparisons with the zinc free form have not been made.

O'Donnell (1941) successfully eliminated fungus from 18 species of fish (including brook, brown, and rainbow trout) by dipping them for 10 to 30 seconds in a 1:15,000 solution of malachite green. In Michigan, the chemical is often used in pond treatments, but the methods vary according to the facilities at the different stations. The flush method is used at one location. Here, water in the pond is lowered to a minimum depth, and a strong solution of malachite is introduced at the head and allowed to progress through the pond in a dense cloud. The treatment lasts about a half-hour. At most stations, ponds are treated regularly with a dilution of 1:180,000 for 45 minutes. Where some other external parasite, such as *Gyrodactylus*, is also present, both malachite green and formalin are combined in one treatment.

Saprolegnia attacks both fish and fish eggs. In trout hatcheries, many man-hours are spent picking dead eggs from hatching trays to prevent the development of fungus, unless prophylactic measures are used. From his

tests of malachite green, formalin, roccal, and hyamine 1622 Burrows (1949) concluded that treatment with malachite green in a dilution of 1:200,000 for an exposure of 1 hour was best for preventing development of fungus; cost of the treatment was low and the eggs had a wide tolerance to malachite green.

CONTROL OF ENDOPARASITES

Comparatively few internal parasites of fish cause mortalities. Three that warrant discussion here are as follows:

Protozoa:

Octomitus salmonis

Cestoda:

Proteocephalus spp.

Trematoda:

Diplostomum flexicaudum

The protozoan parasite, *Octomitus salmonis*, occurs in the intestines of trout and salmon. Serious mortalities at hatcheries among fingerling trout up to 3 or 4 inches long have resulted from infestations by *Octomitus*. Davis (1946) reviewed the symptomatology, life history, pathology, and control measures. Only the control measures will be discussed here. Tunison and McCay (1933) successfully controlled *Octomitus* by adding 0.2-percent calomel (mercurous chloride) to the food for several days. Although calomel may be toxic to fish under certain circumstances, the chemical has been employed commonly in this country for treatment of *Octomitus*. Another chemical, carbarsone, was found by Fish and McKernan (1940) and Nelson (1941) to be just as effective as calomel for control of *Octomitus*, and not toxic to fish. Treatment is made by thoroughly mixing 0.2-percent of carbarsone into the food for 4 consecutive days. We have been using carbarsone successfully in Michigan for both therapeutic and prophylactic treatments. At several hatcheries mortalities from *Octomitus* were experienced annually among brook trout and rainbow trout when the fish were transferred from the troughs to raceways. These losses have been eliminated by 4-day treatments each week for 2 weeks before the fish are moved from the troughs, and for 1 week after they are transferred to the raceways.

Davis (1946) suggested that immune races might be developed. The breeding of trout immune to various diseases is a control measure not fully explored. This phase of disease control will be discussed by Dr. L. E. Wolf in another paper in the symposium.

Although tapeworms rarely cause mortalities of fish at hatcheries, the stocking of infested fish is undesirable because of the possibility of introducing the parasite into waters where it does not occur and the possibility of augmenting an established infestation. Adult tapeworms in the intestine of fish can be removed by the addition of kamala to the diet. McKernan (1940) found 3-inch rainbow trout heavily infested with an undescribed species of *Proteocephalus*. He eliminated the infestation in 1 week by adding 1½- to 2-percent kamala (by weight) to the food. McKernan suggested that the treatment be continued for another week to insure complete

elimination of the worms. According to S. F. Snieszko (private communication), this treatment frees brood stock large- and smallmouth bass of the adult *Proteocephalus ambloplitis*. On his suggestion, Mr. Albert Powell, Superintendent, State of Maryland fish hatcheries, treated largemouth bass with kamala which was introduced into the stomach of the fish in capsules. A dose of about 180 to 220 milligrams of kamala per pound of fish for 3 successive days yielded excellent results; great masses of tapeworms were eliminated from the fish.

The larvae (metacercariae) of several species of strigeid trematodes infest the eyes of fish, causing permanent blindness. Palmer (1939) first reported the infestation in hatcheries. Van Haitsma (1930) traced the life history of the eye fluke, *Diplostomum flexicaudum*, and Ferguson and Hayford (1941) described the life history and control of this parasite at Hackettstown, New Jersey. The life history is as follows: the adult of *Diplostomum flexicaudum* lives in the intestine of gulls; eggs pass into water; eggs hatch and miracidia infest snails of the genus *Lymnaea*; cercariae leave the snail and burrow into fish, localizing in the crystalline lens of the eye; gull eats fish; and the adult worm develops in intestines of the bird. Infestations of this worm may cause high mortalities (through starvation) among small fingerling trout, although hatchery trout from 6 to 9 inches long, blinded by the disease, remain healthy when fed a diet that sinks to the bottom of the pond where they can find it (presumably by scent). Fish can be protected from the eye-fluke by elimination of snails from the pond, thus breaking the life cycle of the parasite.

The control of parasites of fish in lakes and streams usually is not feasible. However, an interesting attempt at the control of a fish parasite in nature was initiated in Alberta, Canada, by Miller (1945). In certain lakes in Canada, the plerocercoid of the tapeworm, *Triaenophorus crassus*, infests ciscoes (*Leucichthys* spp.) and whitefish (*Coregonus clupeaformis*) so heavily that the fish cannot be marketed. The parasite, therefore, is of considerable economic importance to the fishing industry. *T. crassus* lives as an adult in the intestines of northern pike (*Esox lucius*). The first intermediate host is the copepod, *Cyclops bicuspidatus*; a variety of salmonoid fishes, particularly the coregonids, can serve as the second intermediate host. Control methods were directed towards breaking the life cycle of the parasite. An unsuccessful attempt was made to kill free-swimming larvae (coracidia) by acidifying a lake (Miller and Watkins, 1945). Partial control was obtained by drastic reduction of the tullibee population (Miller, 1948) in Lesser Slave Lake, Alberta, but there is no assurance that the benefits will be lasting or that the method would be effective in other lakes. In Square Lake, Alberta, Miller (1950) succeeded in reducing the infestation in tullibee by 39 percent when he reduced the population of northern pike. He concluded that the method was not practical because of the ability of northern pike to repopulate depleted areas very rapidly and because of the high cost of the operation. Control of the short-lived, free-swimming tapeworm larvae is now being studied in the laboratory by Miller (1952), who stated that a long period of research evidently will be necessary to conquer the problem.

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THE GENETICS OF FISH DISEASES ¹

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ABSTRACT

The clearest evidence for the hereditary determination of diseases in fishes comes from the genetic studies of melanomas. This neoplastic disease in platyfish-swordtail hybrids is initiated, intensified, or inhibited by genetic factors. The development of melanomas depends upon the interaction of a sex-linked, dominant gene obtained from the platyfish and a number of dominant modifying genes obtained from the swordtail. During the past 5 years, evidence has been discovered for the hereditary influence in the development of thyroid tumors in a species of Mexican swordtails. The disease closely resembles the well known thyroid tumors in trout, described about 50 years ago. Kidney tumors of thyroid-cell origin have been detected in several strains of platyfish. In other strains of the same species, living under similar conditions and diets, the kidney tumors have not developed. Several examples are presented of death of fish embryos from hereditary causes. Some skeletal abnormalities of fishes may be traced to injurious genes. The hereditary factors involved in diseases and abnormalities are generally complex and difficult to detect, but the evidence for their existence is undeniable.

INTRODUCTION

The progressive fish-culturist who reviews the 2,596 pages of the United States Yearbooks of Agriculture for the years 1936 and 1937 will become vividly aware of the tremendous efforts and expenditures that have been made in the improvement of our domesticated plants and animals by the practical application of genetic principles. These successes have justified continuously greater effort and expenditures to maintain and extend the gains made. It is logical to believe that, given comparable adequate funds for similar research, the fish geneticist could match the successes made by the plant and the non-ichthyological animal geneticist. Fishes have an enormously greater reproductive capacity than other domesticated animals, an advantage of immense potential value to the breeder, since it enables the fish geneticist to utilize some of the techniques heretofore found applicable only to plant breeding. Once a pair of fish with desirable characters has been developed the strain may be multiplied on a large scale. We cannot now review the reasons why plant breeding has advanced beyond animal breeding, nor why animal breeding as applied to fishes has lagged far behind in obtaining its share of benefits from the application of known principles of inheritance.

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To attain their desired goal, fish-culturists must combine some of the techniques of the modern plant and animal geneticists. The breeding methods for trout improvement initiated by the pioneering work of Embury and Hayford (1925), Hayford and Embury (1930), Davis (1931), Lewis (1944), and by methods and objectives suggested by Keil (1936), Millenbach (1950), and Carbine (1953) must be reappraised for some of them are no longer adequate. The suggestions of Wright (1951, 1952) and Wolf (this symposium) are valuable. Perhaps when someone in the future reviews the progress in fish-cultural practices that will have been made in the next 50 years, as Wood (1953) has done for the last century, he may then be justified in devoting more than a single, short paragraph to the accomplishments of applied fish genetics.

DELETERIOUS EFFECT OF SOME COLOR GENES IN THE SWORDTAIL

Some look upon color differences between fishes as being rather superficial, and relatively unimportant in terms of the well-being of the animals, but geneticists have found that some of the genes effecting color are associated with a number of major physiological disturbances. In the golden and albino swordtails, *Xiphophorus helleri*, Gordon (1941) demonstrated that color genes not only are expressed in pigmentation effects but they also, in some manner as yet unknown, bring about the death of some fishes during their late embryonic development.

The ancestral olive-gray coloring of the wild swordtail is a mosaic pattern of two major kinds of tiny pigment-carrying cells, the blacks (micromelanophores) and the yellows (xanthophores). The golden swordtail, by a mutational change in its hereditary constitution, lost all but a few of the black cells, but retained its yellow ones. Its eyes were not involved and are just as black as those of the wild fish. The mutational change which transformed the wild swordtail into the golden must have taken place prior to 1921, for in that year, Krasper, a German aquarist, first described the golden sport. Another aquarist, Hildebrand, claimed that the coloring of the wild swordtail was dominant over the golden. Later, Gordon (1938) showed, in a series of genetic tests, that the golden coloration of the swordtail (gene *gg*) was definitely recessive to the gray (gene *GG*) and was typically Mendelian.

The albino swordtail with its light body coloring and pink eyes was discovered about 1934 in aquaria containing the ordinary, black-eyed, olive-gray swordtails. Curiously, the mutant appeared almost simultaneously in American and in European aquaria. Kosswig (1935) was the first to show that albinism in the swordtail is a recessive hereditary trait. His results were confirmed by experiments conducted independently by Gordon (1941).

The albino mutation (gene *aa*) brought about the almost complete elimination of the black pigment normally present in the skin, in the retina of the eyes, and in all other areas of the body. The albino's eyes appear pink in the swordtail not because of any special red pigment, but

because, as in the pink-eyed albino trout, amphibians, reptiles, birds, and mammals, the pink color comes from the many fine blood vessels in the iris and retina.

When Gordon mated a golden swordtail with an albino, he obtained in the first generation the wild, fully pigmented swordtail. Each of the two parental color varieties, the golden and albino, brought to its offspring one of the essential dominant factors which the other lacked. This example of reversion to the wild type may be expressed as follows:

$$\begin{array}{l} \text{Golden} \times \text{Albino} = \text{Wild, olive-gray} \\ gg AA \times GG aa = Gg Aa \end{array}$$

The wild-colored offspring (of the first generation from golden and albino parents) when mated brother to sister, theoretically should have produced, out of every 16 born in the second generation: 9 typically wild, GA ; 3 golden, gA ; and 4 albinos, Ga or ga . When four pairs of F_1 wild-colored swordtails were mated brother to sister ($Gg Aa \times Gg Aa$), the results in the second generation showed fewer albinos and golden than one might expect on the basis of the expected 9:3:4 ratio.

Several of the gravid, wild gray F_1 swordtail female parents ($Gg Aa$) were killed and dissected. Their embryos were sorted out according to their phenotypes and counted. They were found to be almost exactly in the ratio of 9 gray to 3 yellow to 4 albino. Apparently many of the albino and golden embryos die just short of their full term. The exact nature of the cause of death has not been discovered. Haskins and Haskins (1948) have reported almost identical results with the gray, albino, and golden guppies, *Lebistes reticulatus*.

THE GENETICS OF DWARFS, OR FISHES WITH CROOKED SPINES

Anyone who has observed the growth of a thousand or more fishes, between birth and maturity, has doubtless noticed some physically abnormal specimens. The commonest abnormality is some form of a twisted spinal column. In 1934 Gordon found a dwarf platyfish which carried a round black spot just in front of its tail. The dwarfing was caused by a defective spinal column which was coiled between head and tail. The black spot is inherited as a simple Mendelian dominant trait. Breeding experiments involving this specimen indicated that while the spinal deformity may have been of genetic origin, the manner in which the deformity was inherited was obscure. In one experiment the hunchback female was mated to a normal male. The resulting brood of 64 fish included a single specimen with a deformed spine, but all showed the black one-spot pattern. In a second experiment the hunchback female was mated to another black platyfish hunchback. From this mating 70 young were born and not a single specimen exhibited any spinal abnormality. In a third experiment normal one-spot offspring of deformed parents were mated. In the first brood of 24 a single specimen was a hunchback.

As opposed to these indefinite results, Aida (1930) has described gene-

tic experiments with the Japanese medaka, *Oryzias latipes*, in which a crooked spine, which he called "wavy" was inherited. A second type of spinal deformity which he called "fused" also exhibited a Mendelian pattern of inheritance. However, in Aida's experiments the pattern of inheritance was not quite typical, for when abnormal specimens were mated, the members of the next generation showed a few normal specimens. If "wavy" and "fused" were typically recessive Mendelian traits, no normal individuals should appear when similar abnormal recessives are mated. Inheritance of spinal deformities, among guppies, in typical Mendelian ratios has also been described by Kirpichnikov (1935), Goodrich, *et al.* (1942), and by Rosenthal and Rosenthal (1950).

The clear-cut results obtained in the genetic study of twisted spines in the guppy are not matched in the medaka or in the platyfish. This difference indicates that these characters in some species are difficult to study genetically, especially when environmental conditions may have a pronounced effect. Skeletal characteristics of fishes are easily affected by environmental conditions prevailing during early embryonic development, as has been shown by Stockard (1907, 1921), Hinrichs (1925), Gabriel (1944), and Foster, *et al.* (1949). Therefore, in any genetic study involving skeletal characteristics of fishes the environmental conditions, particularly temperature, should be rigidly controlled.

THE INTERACTION OF GENES AND MODIFIERS

A gene, even though it be dominant, may not have any immediate visible expression of its own. A gene of this nature was detected by Gordon (1938) through its effect when in the presence of a secondary hereditary factor. The following example, taken from Gordon (1946a), shows that the interaction of the two genes produces a special effect. The comet platyfish is characterized by one black line along the upper margin and another black line on the lower margin of the caudal fin. The comet pattern may be referred to the comet gene (*Co*) which behaves as a simple Mendelian dominant factor with reference to the absence (*co*) of that pattern. This may be expressed as follows:

Comet	P_1	Non-comet
<i>Coco</i>	$\times$	<i>coco</i>
Comet	F_1	Comet
<i>Coco</i>	$\times$	<i>Coco</i>
3 Comet	F_2	1 Non-comet
1 <i>CoCo</i> ,	2 <i>Coco</i> ,	1 <i>coco</i>

Now if the comet platyfish, *CoCo*, is mated to a swordtail which does not have the comet pattern, *coco*, their F_1 hybrids develop an entirely new pattern, known as the wagtail. The wagtail pattern is strikingly different from the comet because all the fins, the caudal, dorsal, anal, pectorals, and pelvics, as well as the tip of the snout and some parts of the operculum become black. Like the pattern of the Siamese cat, all the extremities of the wagtail are darkly pigmented.

When 2 F_1 platyfish-swordtail wagtail hybrids are mated, brother to sister, the following types and their ratios appear in the second generation: 9 wagtails; 3 comets; 4 no pattern.

These results were explained by Gordon on the basis of two dominant genes, one of which is readily expressed (the comet gene *Co* of the platyfish) and the other a modifying gene, *E*, (an *extensor* of the effect of *Co*) carried by the swordtail. The *E* gene has no visible effect by itself, even though it is a dominant. It can be detected only in the presence of the *Co* gene. The genetic method of presenting the matings and the data are as follows:

Comet platyfish	P_1	Swordtail
<i>CoCo ee</i>	$\times$	<i>coco EE</i>
F ₁ Wagtail hybrids		
	<i>Coco Ee</i>	
Wagtail hybrid	F_1	Wagtail hybrid
<i>Coco Ee</i>	$\times$	<i>Coco Ee</i>
	F_2	
Phenotypes:		Appearance
9 <i>Co E</i>		9 Wagtails
3 <i>Co e</i>		3 Comets
3 <i>co E</i>		4 No pattern
1 <i>co e</i>		

In the development of the wagtail pattern the blackening of parts of the body never reaches a pathological stage. This is because only small black pigment cells (micromelanophores) are involved. Micromelanophores in great numbers appear, also, over the entire bodies of the melanistic phases of the molly, *Mollienesia*, and the mosquitofish, *Gambusia*, but the genetics of these two species has not been studied sufficiently.

THE GENETICS OF ATYPICAL PIGMENT-CELL GROWTH

In the study of the inheritance of macromelanophore patterns (patterns produced by large black pigment cells) no abnormalities were noticed among the offspring when matings were made between members of the same strain. When, however, a spotted platyfish of one species was mated to a member of another species, their interspecific hybrids showed some abnormalities in the growth of their large pigment cells. Only the spotted patterns involving the macromelanophores produced abnormalities in species hybrids; the micromelanophore patterns remain normal in development in the same hybrid population.

Multiple Factors in the Abnormal Growth of Macromelanophores.—As an aid in visualizing the genetic process involved in the production of melanotic neoplasms in hybrids between the platyfish and swordtail, Kosswig (1931) and Gordon (1937) employed the concept of the multiple-factor hypothesis.

The essential hereditary factor contributed to the melanotic hybrid by its platyfish parent is the sex-linked, dominant factor *Sp*, for macro-

melanophores. The swordtail parent transmits to its abnormally pigmented hybrid offspring two dominant genes which interact with and modify the normal expression of the *Sp* factor of the platyfish. Since these genes have no visible expression in the swordtail parent, they are referred to simply as *A* and *B*. The following genetic formulae may represent the normal parents involved:

Swordtail	×	Platyfish (spotted)
<i>spsp AA BB</i>	×	<i>SpSp aa bb</i>

The first generation hybrids are *Spsp Aa Bb*. This genic composition indicates that the platyfish macromelanophore gene, *Sp*, is now associated with two dominant macromelanophore-growth-intensifying factors *A* and *B*. The *Sp A B* hybrids are highly melanotic and this condition generally leads to the development of melanomas. Further studies on the genetics of melanomas in platyfish-swordtail hybrids were reported by Gordon (1950a, 1951).

Genetics of Red-Black Pigmented Tumors.—Tumors in fishes involving the red pigment cells, xanthoerythrophores, are rare. Rarer still is the phenomenon of the invasion and replacement of one kind of tumor by another, pigmented or not. Gordon (1950a) described the genetics of a mixed-pigmentcell tumor involving red and black pigment cells, an erythromelanoma in platyfish-swordtail hybrids. Later Nigrelli, Jakowska, and Gordon (1951) demonstrated histologically and cytologically that two kinds of pigmentcell tumors were involved, first, a red tumor, a xanthoerythrophoroma of the head region and, second, a black tumor, a melanoma of the tail region. When joined, the two pigmentcell tumors produced an erythromelanoma.

The genetic history of the erythromelanomas which developed in a significant proportion of a single brood of platyfish-swordtail hybrids was traced to a mating between an exceptionally colored male platyfish and an albino swordtail female. The male platyfish had an unusual combination of sex-linked color genes: *Rt* for ruby-throated and *Sp* for spot-sided pattern were linked on the same chromosome. In this arrangement they were carried in the same gamete. If they were not linked, no erythromelanomas were produced in the hybrids. This situation may be illustrated as follows:

A. Linkage of *Rt* and *Sp* on same sex chromosome

Ruby-throated, spotted platyfish × Albino swordtail

$$\frac{Rt\ Sp}{rt\ sp} \times \frac{rt\ sp}{rt\ sp}$$

F₁ Hybrids

1. 50 percent $\frac{Rt\ Sp}{rt\ sp}$, these may develop erythromelanomas.

2. 50 percent $\frac{rt\ sp}{rt\ sp}$, these are normal.

B. No Linkage of *Rt* and *Sp*Ruby-throated, spotted platyfish $\times$ Albino swordtail

$$\frac{Rt\ sp}{rt\ Sp} \times \frac{rt\ sp}{rt\ sp}$$

F₁ Hybrids

1. 50 percent $\frac{Rt\ sp}{rt\ sp}$, ruby-throated hybrids
2. 50 percent $\frac{rt\ Sp}{rt\ sp}$, spotted hybrids, may develop melanomas only.

It will be noted that the platyfish parents in mating *A* and *B* are identical in color since they carried identical genes, *Rt* and *Sp*. Yet the F₁ hybrids they produced when mated to albino swordtails differed.

The production of the erythromelanoma in the platyfish-swordtail hybrids then depends upon the presence of the linked genes *Rt Sp*. These details indicate the preciseness of the genetic (chromosomal) control of pigment-cell development. They also show the importance of studying the various genes and gene combinations and their specific developmental effects upon the normal and atypical growth of specific cells. From these experiments it may be concluded that the spacial relationships of some genes as well as specific gene combinations influence the development of specific tumors.

THE GENETIC BASIS FOR THE DEVELOPMENT OF OCULAR TUMORS

During 1943 to 1946 a number of platyfish, swordtails, and their hybrids in our laboratory developed exophthalmic ocular tumors. Levine and Gordon (1946) diagnosed the disease as a melanoma that developed from the pigmented choroid cells and invaded the retina and interocular region. Subsequently it was discovered that Jahnel (1939) in Germany had found essentially the same disease in some members of a common brood of hybrid swordtails.

An analysis of our animals revealed that most of the exophthalmic fishes with ocular melanomas were genetically related. Gordon (1946b) suggested that a recessive gene, *oc* for ocular tumors interacting with the albino gene *a* was primarily responsible for the disease. In none of the eyes of the affected fishes were extraneous organisms found.

CATARACTS TRACED IN FIVE GENERATIONS OF PLATYFISH

A female platyfish was discovered with a cataract in one of its eyes, blinding it in that eye. It was mated to a closely related but normal male. Gordon (unpublished) found that all of their offspring (first generation) had normal eyes. When these were mated, they produced 43 second-generation fish 1 of which, a male, had a cataract. Unfortunately the cataractal male was unable to mate. Ten pairs of normal second-generation fish

were mated. Three pairs each produced 1 cataractal fish in the third generation.

One of the cataractal females of the third generation when mated with its brother produced 5 broods totalling 115 fish of which 20 had cataracts. It was not possible to carry the analysis beyond the fourth generation. The distribution of the cataractal fish through 5 generations is so erratic that no clear-cut genetic analysis is possible. It may be said, however, that cataracts in the platyfish are inherited in a manner not yet determined.

GENETICS OF THYROID AND KIDNEY TUMORS

Marine and Lenhart (1910) and Gaylord and Marsh (1912) showed that thyroid tumors in hatchery-reared brook trout (*Salvelinus fontinalis*) developed from hypertrophied and hyperplastic thyroid tissue. The tumors invaded and replaced muscle and bone. Much later Gorbman and Gordon (1951) described a somewhat similar tumor in laboratory-reared Montezuma swordtails, *Xiphophorus montezumae*, originally obtained from the Río Panuco in Mexico.

The laboratory-reared swordtails have been propagated since their initial introduction in 1939 by methods described by Gordon (1950b). The fish were kept in conditioned fresh water that, for many years, had been used over and over again. This conditioned water was interchanged among the tanks containing members of six other species of xiphophorin fishes. The diet of all seven species of fishes contained dried shredded ocean shrimp, liver, cereal, and living tubificids and daphnids.

Later, Berg, Edgar, and Gordon (1953) described the genetic history and the developmental stages of the thyroid tumor in various sublines of inbred laboratory-reared Montezuma swordtails. The thyroid tissue of these fishes was also compared to similar glands obtained from wild swordtails taken from their natural habitat and fixed at the site of their capture, in Mexico. One laboratory strain called 38³, represents 7 generations of inbreeding, the last 3 by brother-to-sister matings. The second strain, called 43, has a similar genetic history for the first 4 generations; the last 3 generations represent close inbreeding but not by brother-to-sister matings.

Baker and Gordon (1953) made some preliminary studies of the differential susceptibility of various strains of the platyfish, *Xiphophorus maculatus*, to a kidney tumor. The kidney tumors are cystic and show features of papillary adenoma, others of adenocarcinoma. The susceptibility of the platyfish to these tumors appears to be genetically determined. Under identical conditions of maintenance, various pure lines derived from wild populations and from fanciers' stocks have widely differing incidences of the disease. Estimates based on gross examination of hundreds of preserved specimens accumulated over several years from the laboratory-reared stocks, and of currently maintained animals, indicate that the incidence of the tumors may be very high (50 percent) in some lines and zero in others.

More recently, Baker, Berg, Nigrelli, Gorbman, and Gordon (1954) have announced that the thyroid glands of fishes with tumorous kidneys are hyperplastic, extending dorso-ventrally from the floor of the mouth into the jaw muscles, laterally to the gills, and posteriorly to the heart. Thyroid cells infiltrate along muscle fascia and larger blood vessels into the choroid gland of the eye, the pericardium, and kidney, but not the liver. Cell continuity between thyroid and kidney tumors is traceable along the roof of the pericardium and cardinal sinuses. Radioactive iodine injected into tumorous fishes yielded definite radioautographs from cross-sections through the kidney and thyroid regions.

GENERAL COMMENTS AND CONCLUSIONS

Positive evidence that heredity plays an important role in the development of cutaneous melanomas by the platyfish-swordtail group of fishes has been obtained independently by Kosswig, Breider, and Gordon (for references, see Gordon, 1951). Hereditary factors are also important in the development of ocular melanomas. Apparently the latter is unrelated genetically to the former. Some of the principle genes responsible for the development of these diseases have been identified; the most thoroughly analyzed one is that of the cutaneous melanomas.

The results of all the genetic experiments concerned with normal and atypical pigmentcell growth in fishes may be explained within the framework of present-day principles of mendelian inheritance. The hereditary control of melanomas in hybrid fishes rests not on one gene but on a constellation of genes. To be effective this assemblage of genes must contain within it a gene for macromelanophores, the pigment cells that are sensitive to the influence of genic imbalance.

The spontaneous thyroid tumors and kidney tumors are apparently under genetic influence, but the actual genes involved have not yet been identified.

A gene responsible for abnormal spines has been discovered in a number of fishes. Many of the variations of the goldfish would be regarded as being abnormal, if they occurred in other species. Many of these abnormalities of the goldfish, according to a review by Gordon (1950b), are inherited in a complex manner. From time to time numbers of individuals of a single species of fish in nature are reported to have similar abnormalities; some for example, have no anal fins, some are susceptible to a particular disease. As an illustration, Schlumberger (1950) reported that 5 percent of the goldfish in a large urban pond developed cutaneous neurofibroma and some also had polycystic kidneys. He suggested that possibly genetic factors were involved.

Abundant evidence thus exists for the genetic control of certain diseases and abnormalities in fishes. The known facts with respect to fishes parallel those known for genetic control of diseases and abnormalities in other vertebrate animals including man. The hereditary factors involved in disease and structural abnormalities are generally complex and difficult to detect, but the evidence for their existence is undeniable.

Given the time, sufficient financial support, an adequate and modern program of research, the fish geneticist could match, with fishes, the spectacular successes that plant and non-ichthyological animal geneticists have had in the improvement of their farm plants and land animals.

A series of articles on the principles of inheritance for the fish fancier has been prepared by Gordon (1952-1954).

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THE NATURE OF BACTERIA PATHOGENIC TO FISH

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ABSTRACT

A review is made of the progress in research on bacteria which are pathogenic to fish, with particular emphasis on those investigations performed during the past decade. The report includes a critical review of material published; the comments and suggestions are designed to stimulate the initiation of new research projects.

INTRODUCTION

Many microorganisms found in and associated with water have proved of great value as implements to further knowledge of a fundamental character. More is to be learned of the nature, physiology, and relation of these diminutive plants to other forms of life, particularly with reference to the phenomenon of diseases in cold-blooded animals.

The bacteria discussed in this paper are principally those most widely recognized as causes of fish diseases. As few microbiologists are engaged actively in research on the nature of fish pathogens, there is a paucity of data to review. Nevertheless, encouraging progress has been made during the last decade—enough to allow one to view the future with enthusiasm.

MYXOBACTERIALES

The myxobacteria may be considered as “higher bacteria” because of structural and/or developmental features analogous to those of certain other forms of life. The microorganisms are usually long, slender, flexible, nonflagellated vegetative cells which on occasion lead an unusual type of communal existence. The cells are surrounded by quantities of a slimy matrix which imparts a moist appearance to the colonies. These “colonial cells” characteristically exhibit a gliding or slithering motion and the individuals frequently move *en masse*. Most possess a relatively complex life cycle which, for convenience, can be divided into a “swarm state” and an “encystment stage”. In the former, the vegetative cells may be parallel, singly or in groups. In the final stage, the formation of cysts and then fruiting bodies occurs among members of certain families of this order. The rods may gather at various loci and pile up on the surface to

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form stalk-like structures on the ends of which the fruiting bodies develop (the slimy matrix apparently dries and the cells are thus encysted to form the body). Favorable growth conditions may then influence the fruiting structures to break open; the bacteria move out into the surrounding medium, new slime-covered colonies are formed, and the "swarm state" begins anew. Most members of this peculiar group are only saprophytic and can be found in manure, soil, rotten wood, straw,

Columnaris disease.—An exception is those myxobacteria reported to be pathogenic for fish. Davis (1922) was possibly the first to recognize an organism which caused a "mold-like" growth on the skin and fins of fish which were held in aquaria. The microorganism was described as a long, slender, flexible rod which exhibited a peculiar sinuous movement. The organisms collected together about a fragment of scale debris for example, to form short columns or dome-shaped masses (hence the name "columnaris disease"). These observations suggested that these organisms were members of the Myxobacteriaceae, but at the time of Davis' report little was known of this unique group and the now familiar name, *Bacillus columnaris*, was therefore aptly applied. A discussion of the myxobacteria by Rucker, Earp, and Ordal can be found in another section of this symposium.

Gill Diseases.—Like pneumonitis in man, the term gill diseases is to be preferred over the singular designation, gill disease. The discussion will be limited to those instances in which bacteria have been consistently associated with impaired gill function. It is difficult to discuss the nature of the associated microorganisms since the etiology is still obscure. Ordal and Rucker (1944) isolated myxobacteria, which did not produce fruiting bodies, from the gills of infected fish. From the discussion of Rucker, Johnson, and Kaydas (1952), it would appear that the filamentous bacteria associated with this disease are not necessarily all of the same type. In the same paper these authors referred to the observations of Burrows concerning a bacterium which formed plaque-like colonies on the gill filaments. Typical filamentous bacteria were noted in association with the plaques, the latter disappeared, and only the filamentous microorganisms remained. This description finds an analogy in the phenomenon of columnar formation in columnaris disease.

At this time all attempts to transmit the disease artificially have failed. This fact in itself does not preclude the possibility that these bacteria are the agents of a type of gill disease since similar difficulties exist in certain other diseases (e.g., syphilis, leprosy) in which the organism, once cultured, somehow loses some or all of its pathogenic qualities.

Aeromonas salmonicida (FURUNCULOSIS)²

Little has been published on the nature and characteristics of this microorganism in the last decade. The reader is referred to the excellent review of furunculosis by McCraw (1952) for previous research on this bacterium.

² In the next edition of Bergey's Manual of Determinative Bacteriology, *Bacterium salmonicida* will be placed in the new genus *Aeromonas*, (Kluyver and van Niel).

The first significant diagnostic method in detecting furunculosis came with the formulation of a casein digest-yeast extract medium (Gutsell and Snieszko, 1949) which is particularly suited to demonstrate the characteristic amber-black pigment produced by this bacterium. The pigment is used as the criterion for the presumptive bacteriological diagnosis of the disease. Although the method is highly reliable, diagnosis is conditional since other microorganisms are known to produce similar pigments (Clark and Smith, 1939; Ensminger, 1953; Klykov, 1945; Ungerer, 1934). For example, *Pseudomonas calco-acetica*³ slowly produces a pigment in a manner almost indistinguishable from that of *A. salmonicida*. A differentiation could be made, however, by applying paraphenylenediamine to the surface of the colonies (Griffin, 1952c; Griffin, Snieszko, and Friddle, 1953c). In conjunction with motility tests, the procedure serves adequately as a presumptive test for *A. salmonicida* even before a pigment develops.

In view of the widespread occurrence and economic importance of furunculosis, a curious anomaly existed: the microorganism was first isolated and described nearly 60 years ago but until recently a complete description was lacking. Consequently only a superficial reference can be found in Bergey's Manual (Breed, Murray, and Hitchens, 1948). Accordingly, an investigation was undertaken to establish descriptive data to be used as a reference in the identification of the microorganism. The details may be found in the publication of Griffin, Snieszko, and Friddle (1953a).

In the choice of a medium for the bacteriological diagnosis of furunculosis in fish, the process of pigmentation assumes considerable importance. Availability of oxygen, proper temperature of incubation, and suitable composition of the medium are essential to pigment formation. L-tyrosine or L-phenylalanine are the parent compounds in the formation of the melanin-like pigment (Griffin, 1952b). Other substances will also act as substrates for the enzyme or enzyme systems in *A. salmonicida*, as for example, D-phenylalanine, glycyl-L-phenylalanine, and B-2-thienylalanine which can substitute for L-phenylalanine; L-tyrosine ethyl ester and glycyl-L-tyrosine can be substituted for L-tyrosine. The color and intensity of the resultant pigments vary according to the material used. To cite but one example, a bright salmon-pink color is produced through the use of B-2-thienylalanine. That the pigment is a result of phenylalanine and tyrosine metabolism has been conclusively proven since pigmentation does not occur in a defined medium which lacks the amino acids or various substituents indicated above (Griffin, Snieszko, and Friddle, 1953b). These same authors also suggested the conversion of phenylalanine to tyrosine which was recently demonstrated by Mitoma (1954). The same conversion occurs in humans but few, if any, other bacteria have been reported to have this capacity.

The problem of the properties which give *A. salmonicida* its pathogenic quality is exceedingly complex; indeed, a complete explanation has not been found even in studies of other bacterial diseases.

One method of approach to understanding is offered by direct study of the disease agent itself; the observations of the requirement by *A. sal-*

³ Culture obtained from Dr. W. C. Haynes, U. S. Department of Agriculture, Peoria, Illinois.

monocida for the amino acid arginine may be taken as a case in point. A common pathway in the metabolism of arginine by certain other microorganisms is its conversion to ornithine. A simple decarboxylation of these products would form agmatine (from arginine) and putrescine (from ornithine). Tyrosine, shown to be important in pigmentation, might also be decarboxylated to tyramine. These substances are physiologically or pharmacologically active and, if formed, would play a role in the disease process. For example, agmatine possesses insulin-like properties; the effect of this amine would be to remove glucose from the blood stream. Field *et al.* (1944) have presented evidence for a dramatic hypoglycemia in fish with acute furunculosis. It was suggested that the microorganism utilizes the blood sugar in its metabolism (the fermentation of glucose has been demonstrated *in vitro* by various investigators) and that the hypoglycemic shock thus induced, contributes to the fatalities. Increased urea and creatine values also found by these same investigators probably reflect the extreme tissue destruction caused by proteolytic enzymes produced by *A. salmonicida*. The presence of larger amounts of creatine is significant since it apparently indicates disintegration of muscle tissue. Although *A. salmonicida* produces a hemolysin, the contribution which this enzyme makes to the pathology is small since Field *et al.* (1944) indicated that hemoglobin and erythrocyte values (in fish inoculated with *A. salmonicida*) were essentially the same as those found in the uninoculated controls.

Davis (1946) noted that furunculosis is particularly common among mature trout during and shortly after the spawning season. The usual explanation is that the exacerbation of disease is primarily a consequence of rough handling of the fish when spawn is taken. This view appears logical enough and undoubtedly handling is an important factor; however, other possible influences should be considered. Arginine is intimately involved in the growth of *A. salmonicida*, and so also are histidine, asparagine, lysine, methionine, and probably leucine.⁴ It is striking that, except for leucine and methionine, all the other amino acids concerned in the *in vitro* growth of *A. salmonicida* are predominantly basic in reaction. In an actual infection, these amino acids are supplied to the organism by the fish. Protamines, the characteristic proteins of ripe sperm cells (*e.g.*, salmine from salmon, clupeine from herring, . . .), are especially rich in basic (diamino) amino acids (arginine for example, constitutes approximately 87-91 percent of the total nitrogen in clupeine). The "carrier state" and latent infections have been shown to exist in furunculosis and to represent delicate balances between host and parasite. Any condition tending to affect the fish adversely, *e.g.*, low oxygen, poor diet, infestation, would necessarily disrupt the delicate adjustment and favor the pathogen. Conversely, anything tending to enhance the growth and development of the microorganism might have the same effect. Once part of the metabolic machinery of the fish is turned to the production of these basic amino acids, a more favorable environment is created for the microorganism.

⁴ P. J. Griffin and associates, unpublished observations (1953).

The Furunculosis Committee isolated *A. salmonicida* from the ovaries of infected trout (McCraw, 1952); it would be desirable to look for these organisms in testes also. Some support for the belief that the pathogen may occur in the testes comes from the observations on an outbreak of furunculosis by Stevens and Keil (1931); just prior to the spawning season, a large number of fish developed lesions and the progress of the disease was rapid, particularly among the male fish. Similar observations have been made by others.

A constant feature of furunculosis is the absence of marked leukocytic infiltration. Blake (after McCraw, 1952) indicated that blood films showed considerable numbers of free bacteria and relatively little phagocytosis. Field and associates (1944) stated that the blood picture in fish inoculated with *A. salmonicida* was essentially the same as that found in the control animals. This is anomalous in view of the widespread tissue involvement incident to this disease. Possibly the absence of chemotaxis means that the organism produces a leukocidin; a type of histone may be involved; the demonstration of hyaluronidase ("spreading factor") also would add to an enlightened understanding of the pathogenesis.

The difference noted in the leukocytic response of fish to the agent of ulcer disease suggests a convenient method of diagnosis, since in this disease, as opposed to furunculosis, a marked leukocytic infiltration is a constant feature. Total white blood cell and differential counts may be of value in predicting the disease even before obvious external symptoms (which are frequently misleading) appear and bacteriological examinations are made. Although cases of mixed infections might be confusing, such an approach might indeed prove to be fruitful.

Older concepts of disease as the result of mechanical action alone are, of course, no longer acceptable (Bodansky and Bodansky, 1952). Possibly certain additional concepts of mechanical defense against infection in fish as, for example, an intact slime layer as a physical barrier to infectious agents, may need some modification. Protective substances such as lysozyme in tears, inhibine in saliva and virus-inactivating agent (V.I.A.) in nasal secretions, are known. Similar bacterial antagonists may occur in the slime which surrounds the fish.

Hemophilus Piscium (ULCER DISEASE)

The name "ulcer disease" generally has been applied to a number of diseases of fish characterized by external ulceration. Snieszko (1952) suggested that the term be restricted to that condition caused by *Hemophilus piscium* and having the symptoms and pathology described by Fish (1934) and Wolf (1939). This restriction serves to establish the nature and agent of this disease and thus eliminates confusion with ulcerative conditions caused by a host of other microorganisms. This limitation is important since Davis (1946) indicated that brook trout (*Salvelinus fontinalis*) inoculated with *A. salmonicida* by pricking the skin with a needle, developed lesions identical with those from typical ulcers of a natural infection. Reed and Toner (1941) reported a "red sore" disease

in northern pike (*Esox lucius*) and in brook trout; however the organism isolated was *Pseudomonas hydrophila* (*Aeromonas liquefaciens* according to the new nomenclature). Flakas (1950) recovered both a gram positive rod and *A. salmonicida* from ulcerative lesions on yearling brook trout. The suggestion of some synergistic action was made but the hypothesis was not tested further.

Snieszko and Friddle (1950) first isolated *H. piscium* from the ulcers, blood, and kidneys of diseased fingerling brook trout by utilizing a medium enriched with blood or other natural products. A complete description of the microorganism soon followed (Snieszko, Griffin, and Friddle, 1950). The need for a thermolabile factor, essential to growth, was indicated. Griffin (1951) reported that a phosphorylated moiety was involved and that diphosphothiamine (cocarboxylase) and adenosine triphosphate (ATP), in exceedingly low concentrations could substitute for crude materials. The same author (1952a) indicated that in the presence of cocarboxylase or ATP, the growth response to the thermostable compound hemin (X factor) was comparable to that in media containing crude substances. Adenosine monophosphate and adenosine diphosphate were found capable of supporting growth to varying degrees and curiously, thiamine proved inhibitory. Either the phosphorylated derivative of thiamine (cocarboxylase) or ATP was capable of reversing the inhibition.

Ulcer disease in fishes has a striking counterpart in tularemia in humans, especially in the clinical type of tularemia known as ulceroglandular. In this disease, the organism (*Pasteurella tularensis*) is retained at the site of the local lesion for a period of days—probably a result of mechanical effects of local inflammation and the host's immune response. The primary lesion usually appears at the point of a microscopic scratch or cut. In 3 or 4 days a papule forms and by 7 or 8 days an open ulcer develops. (The reader is referred to the descriptions of ulcer disease given by Wolf (1939) and Davis (1946) for comparison). This remarkable similarity may be more than fortuitous since both *Past. tularensis* and *H. piscium* require the same thermolabile growth factors (Tamura and Fleming, 1949; Griffin, 1951). Possibly a greater familiarity with pathogenesis in tularemia would lead to a better understanding of the process in ulcer disease.

INFECTIONS CAUSED BY PSEUDOMONADS

Members of this group are gram negative, usually polar-flagellated bacilli, widely distributed in nature, and frequently productive of water-soluble pigments. Many members of this genus are pathogenic for both marine and fresh-water fishes.

Wells and ZoBell (1934) described an infective dermatitis in certain marine fishes caused by *Achromobacter ichthyodermis*. Later, ZoBell (1946) indicated that the organism should be designated *Pseudomonas ichthyodermis*, since it possessed a polar flagellum. Fish (1934) reported the presence of *Proteus hydrophila* in an ulcerative condition of brook trout and Wolf (1937) tentatively identified *Ps. fluorescens* as the etiologi-

cal agent of an air bladder disease of lake trout (*Salvelinus namaycush*) fingerlings.

In Germany, Schäperclaus and Mann carried out extensive studies on carp (*Cyprinus carpio*) dropsy. Their results are summarized in a monograph (Mann, 1939; Schäperclaus, 1939; Schäperclaus and Mann, 1939). Investigations on the same disease were carried out by Snieszko *et al.* in Poland (1938; English summary, 1940) who isolated the same micro-organism (*Ps. punctata*) and reported that the biological characteristics of all isolated cultures were identical with those described by Schäperclaus. The bacteria isolated in Poland formed a serologically heterogeneous group. An interesting work on the immunization of carp with *Ps. punctata* was published by Mann (1939).

Although the symptoms of the disease in carp often were variable, the most frequent extreme signs were deep ulcers penetrating the skin and underlying musculature and a dropsical condition which, according to some, is caused by a variant (*Ps. punctata* v. *ascitae*). The final stage of the disease is a general septicemia.

Schillinger (1949) discussed the efficacy and practicability of immunizing carp against septicemia. A similar topic was treated by Marek (1950). Reed and Toner (1941) isolated *Ps. hydrophila* from the organs and blood of northern pike suffering from "red sore" disease. These same authors (1942) again isolated the organism from northern pike, brook trout, and frogs and suggested that frogs act as carriers of the organism from one body of water to another. The organism is identical with the etiological agent of "red leg" in frogs and through the years, a variety of generic and specific names have been applied. The following are synonyms: *Bacillus ranicida*, *Bacillus hydrophilus fuscus*, *Bacterium hydrophilus fuscus*, *Proteus hydrophilus*, and *Pseudomonas hydrophila*. Kulp and Borden (1942) pointed to the presence of polar flagellation, indicating that the generic name *Proteus* did not apply. Guthrie and Hitchner (1943) found few significant differences between the characteristics of strains classified as *Proteus hydrophilus* (that had been isolated from frogs, northern pike, and trout) and those of *Pseudomonas punctata*. Stanier (1943) states that *P. hydrophilus* should be termed *Aeromonas hydrophila* because of the vigorous manner which these organisms ferment carbohydrates. Snieszko⁵ compared the characteristics of various cultures of bacteria described as *Pseudomonas punctata*, *Proteus hydrophilus*, *Pseudomonas hydrophila*, *Proteus melanovogenes* (Miles and Miles, 1951), *Aerobacter liquefaciens*, *Pseudomonas hirudinis* (Büsing, 1952), and a number of other cultures of monotrichous, carbohydrate-fermenting bacteria isolated from water and from healthy and infected fish. From this study he concluded that all of these bacteria belong to the same species and that on the basis of rules of bacterial taxonomy, the name *Aeromonas liquefaciens* should be applied.

Hodgkiss and Shewan (1950) recorded an infection in a plaice (*Pleuronectes platessa*) caused by what they regarded as *Pseudomonas ichthyo-*

⁵ S. F. Snieszko, unpublished observations (1953).

dermis. Margolis (1951) reported a hemorrhagic septicemia in northern pike ("red sore" disease) caused by *Ps. hydrophila*. The organism was recovered from the intestines and slime of several other fish, none of which showed any signs of the illness. Rucker and Whipple (1951) isolated a pathogenic fluorescent pseudomonad from yearling sockeye salmon (*Oncorhynchus nerka nerka*) and Seaman (1951) described a pathogenic pseudomonad isolated from rainbow trout (*Salmo gairdneri*). A definite taxonomic position was not assigned to the organism because of the lack of additional experimental data. Wagner and Perkins (1952) also isolated a Pseudomonad from infected rainbow trout. The disease was referred to as "red mouth" disease and the offending microorganism was characterized as *Ps. hydrophila*. Brunner and Striegel-Jaxtheimer (1951) isolated *Ps. punctata* from carp with infectious dropsy, however, another bacterium ("Bacterium münchen") was isolated from the majority of the fish. This organism was not identical with either *Ps. punctata* or *Ps. hydrophila*. An important event was the isolation of "Bacterium münchen" from the copepod, *Argulus foliaceus*, which had sucked blood from diseased carp. This mode of transmission has interesting implications not only with respect to the transmission of carp dropsy but for other diseases as well. Brunner and Striegel-Jaxtheimer (1953), after additional studies on "Bacterium münchen", concluded that this microorganism is distinct from *Ps. punctata* and represents a new species. The name *Pseudomonas granulata* was applied. Dombrowski (1953a; 1953b) disagreed with the former authors and considered the differences to be too slight to justify the naming of a new species. Schäperclaus (1939) suggested the possible involvement of a virus in this disease, possibly in association with *Ps. punctata*. Roegner-Aust, Brunner, and Jaxtheimer (1950) reported that infectious dropsy of carp is primarily viral. The virus-like particles were seen under the electron microscope inside the infected, and apparently normal, carp eggs. This observation suggests the possibility of the transmission of this disease by means of eggs. Marek (1950) also alluded to reports of Soviet investigators who consider a virus as the primary cause of carp septicemia, and a recent work by Brunner and Zöbe (1953) lends additional support to this view. However, Dombrowski (1953c) questioned the viral etiology of this disease. Wunder and Dombrowski (1951) reported on the transmission of carp dropsy by parasitic copepods and leeches. On the basis of the above information, and the fact that many of the terrestrial invertebrate animals serve as carriers of virus diseases for other groups of animals (or even plants) one can speculate on the role of many parasites in the transmission of bacterial and viral diseases of fishes.

MISCELLANEOUS DISEASES

This section concerns those diseases of fish to which reference is made only infrequently, either because the diseases are not widespread or occur frequently but are not generally recognized.

Tuberculosis.—It is questionable whether tubercle-like lesions in fish are related to tuberculosis in higher animals. Nevertheless, the lesions do

resemble more or less those found in classical tuberculosis, and acid-fast bacilli are implicated. Since only a few cultures of such microorganisms have been studied, it is equivocal whether those reported are actually members of different species. Reports of Mycobacteria found in fish are recorded by Aronson (1938). Baker and Hagan (1942) isolated *Mycobacterium platypoecilus* from Mexican platyfish (*Platypoecilus maculatus*) and Nigrelli (1943) found acid-fast bacilli in tropical fish of various genera and species. More recently, Earp, Ellis, and Ordal (1953) reported acid-fast bacilli in enormous numbers in adult chinook salmon (*Oncorhynchus tshawytscha*) showing gross kidney lesions. The question of the possible importance of tuberculosis caused by "cold-blooded" mycobacteria in marine habitats was raised.

Kidney Disease.—The disease, characterized by white, raised areas of necrotic tissue, particularly in the kidney, is caused by small gram-positive, nonmotile, diplobacilli which are usually less than 1 micron long. The organisms occur intra- and extracellularly. They are not filterable and have been reported as culturable *in vitro* (Earp, Ellis and Ordal, 1953). Belding and Merrill (1935) were possibly the first to describe the disease. However, the organism which they isolated was motile and upon inoculation into fish did not reproduce the disease they observed in the natural infection. The organisms have been found in brook trout, brown trout (*Salmo trutta*) and rainbow trout and also in sockeye salmon (Ordal and Earp, 1950; Earp, 1950⁶; Rucker, *et al.*, 1951). At present, the taxonomic position of this microorganism is uncertain.

Mohamed (1939) observed intra- and extracellular minute bodies in the blood of a dead fish which had necrotic ulcers on its body. The organisms, minute coccoid forms varying from 0.2 to 0.4 micron in diameter, frequently occurred in pairs, and were seen inside monocytes and also in the plasma. Mohamed gave these organisms the name *Rickettsia pisces* and stated that his report contained the first published record of a *Rickettsia* in fish. This disease appears to resemble "kidney disease" in this country.

A few other microorganisms, isolated within the last decade or so, have been described inadequately or are still of an undetermined taxonomic position. Flakas (1950) isolated a motile, gram-negative, microaerophilic bacillus from infected black crappies (*Pomoxis nigromaculatus*) and tentatively assigned it to the genus *Spherocillus*. The lesions produced in this disease were relatively wide, swollen, hemorrhagic areas which appeared on only one side of the body, behind and slightly above the pectoral fin. The description of the lesion site coincides with that given by Griffin and Snieszko (1951) of an infection of tropical fish caused by a motile, gram-negative bacillus which proved to be a facultative anaerobe. This organism is of unique taxonomic position in that biochemically it resembles *Paracolobactrum aerogenoides*; however, the presence of a single flagellum places it in the genus *Pseudomonas*. According to unpublished work recently

⁶ Earp, B. J. 1950. Kidney disease in young salmon. 65 pp. [Typewritten thesis; University of Washington]

completed by Snieszko (1953), this bacterium is identical with *Aeromonas liquefaciens* (cf. above). Margolis (1951) reported the isolation of a peritrichic, gram-negative bacillus from a diseased white sucker (*Catostomus commersoni*). This bacterium was classed as a member of the genus *Paracolobactrum*. It is practically identical in all other respects to the monotrichic form described by Griffin and Snieszko (1951).

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FISH DISEASES AND NUTRITION

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ABSTRACT

Malnutrition in fish population, although recognized by the earliest workers in fish culture, has only recently received intensive study commensurate with that in other fields of animal nutrition. Recent experimental test diets have produced specific deficiency syndromes for most of the vitamins and have indicated the possibility of developing specific deficiencies for amino acids, fatty acids, and other basic nutrients. During the past 3 years the first evidence of susceptibility to bacterial disease in lots of fish with sub-clinical manifestations of vitamin deficiencies has opened an entire new field in fish-disease study.

In this review (a portion of a symposium on fish diseases) the nutrition of salmonids is emphasized. Advancements within the last 10 years in the fields of avitaminosis, hypervitaminosis, susceptibility to disease and general malnutrition are mentioned and a table is included which compares the specific avitaminosis syndromes observed in fish with those observed in other experimental animals.

INTRODUCTION

Malnutrition in fish populations, although recognized by the earliest workers in fish culture, has only recently received intensive study commensurate with that in other fields of animal nutrition. Heretofore, attempts to investigate the role of specific nutrients in fish nutrition have been hampered by the lack of suitable test diets in which the factors in question could be controlled experimentally. Recent experimental test diets have enabled investigators to produce specific deficiency syndromes and have laid foundations for controlled study of fish nutrition. Within the last 3 years, the first indications of susceptibility to bacterial disease in fish showing sub-clinical manifestations of specific vitamin deficiencies have opened an entire new field in fish-disease study. These advances promise an increased activity in the study and establishment of the nutritional requirements of fish; and the description, detection, and prevention of nutritional-deficiency syndromes may be made on a more rational basis in the near future.

In this review of the advancements in fish nutrition within the last 10 years, only the nutrition of salmonoid fishes will be discussed because this group is available for close examination in artificial environmental conditions and is one on which there is sufficient literature to warrant a review. In the natural state probably only sub-clinical manifestations of nutritional deficiencies appear because the natural food supply is rich in the

basic nutrients and growth factors. Under hatchery conditions, however, where economy demands the use of artificial diets, nutritional deficiencies may become a serious problem. Detection and prevention of the deficiency syndromes not yet adequately described remain difficult since the specific nutritional requirements of fish of various species have not been established. Sub-clinical deficiency syndromes are at present the greatest problem and until better detection methods are developed, or until the nutritional requirements are defined for the species, no practical diet can be formulated with assurance of nutritional balance.

AVITAMINOSIS

Investigations of the role of vitamins in fish nutrition and observations of general vitamin deficiency syndromes were well established more than ten years ago and still continue actively. A number of workers observed a thiamin deficiency in trout and salmon when a portion of the diet consisted of fresh or freshly frozen fish tissue (Tunison *et al.*, 1942; Wolf, 1842; Woodbury, 1943; Burrows, Robinson, and Palmer, 1951). Simmons and Norris (1941) reported that an anemia in young silver salmon, *Oncorhynchus keta*, and chinook salmon, *Oncorhynchus tshawytscha*, could be cured by injecting xanthopterin, and other workers prevented an anemia in brook trout, *Salvelinus fontinalis*, by feeding a mixture of riboflavin, pyridoxine, and pantothenic acid (Tunison *et al.*, 1943). By changing the proportions of the different ingredients in the ration, tentative vitamin requirements for rainbow trout, *Salmo gairdneri*, brown trout, *Salmo trutta*, and brook trout were determined (Table 1).

The possibility of a test diet was seen by workers developing a meatless ration for trout (McLaren, Herman, and Elvehjem, 1946), and a diet consisting of commercial casein, starch, fish-liver oils, crab meal, minerals, and vitamins was formulated (McLaren *et al.*, 1947b). Deficiency syndromes for some of the water-soluble vitamins were reported for 4-month-old rainbow trout by McLaren *et al.* (1947a). The descriptions of the various specific vitamin-deficiency syndromes are presented in Table 2. Feeding trials with salmon fingerlings and more prolonged feeding periods with trout failed to substantiate the adequacy of the McLaren test diet without a fresh-liver supplement (Rucker, Johnson, and Kaydas, 1952).

A diet was developed which could be used to develop vitamin deficiencies in trout for some of the water-soluble vitamins (Wolf, 1951). The need for pantothenic acid, inositol, and folic acid was demonstrated but no deficiencies could be shown when niacin, biotin, ascorbic acid, vitamin B₁₂, vitamin K, or vitamin E were individually omitted from the diet. Except for a short feeding trial, sufficient to develop a pantothenic-acid deficiency (Rucker, Johnson and Kaydas, 1952), the diet was not tested on salmon fingerlings.

Work with chinook salmon made it apparent that existing diets could not be used during the short fresh-water feeding period because the residual vitamin activity in the basal ration prevented the development of a deficiency syndrome for certain vitamins. A vitamin-free basal ration was

TABLE 1.—Vitamin requirements of trout

Vitamin	Species	Milligrams per kilogram body weight per day	Author
Thiamin.....	Brook	0.15 — 0.19	Phillips <i>et al.</i> , 1946
	Brown	0.15 — 0.19	Phillips <i>et al.</i> , 1946
	Rainbow	0.15 — 0.19	Phillips <i>et al.</i> , 1946
Riboflavin.....	Brook	0.44 — 0.68	Phillips <i>et al.</i> , 1946
	Brown	0.44 — 0.68	Phillips <i>et al.</i> , 1946
	Rainbow	0.44 — 0.68	Phillips <i>et al.</i> , 1946
Pyridoxine.....	Unknown	0.23 — 0.25	Tunison <i>et al.</i> , 1944
Pantothenic acid.....	Unknown	1.11 — 1.45	Tunison <i>et al.</i> , 1944
	Brook	0.99 — 1.25	Phillips <i>et al.</i> , 1945
	Brown	0.99 — 1.25	Phillips <i>et al.</i> , 1945
	Rainbow	0.97 — 1.25	Phillips <i>et al.</i> , 1946
Niacin.....	Brook	3.0 — 4.1	Phillips <i>et al.</i> , 1947
	Brown	3.0 — 4.1	Phillips <i>et al.</i> , 1947
	Rainbow	3.0 — 4.1	Phillips <i>et al.</i> , 1947
Biotin.....	Brook	0.01 — 0.03	Phillips <i>et al.</i> , 1947
	Brown	0.04 — 0.08	Phillips <i>et al.</i> , 1947
	Rainbow	0.01 — 0.03	Phillips <i>et al.</i> , 1947
Folic acid.....	Brook	0.15 — 0.18	Phillips <i>et al.</i> , 1949
	Brown	0.15 — 0.18	Phillips <i>et al.</i> , 1949
	Rainbow	0.15 — 0.18	Phillips <i>et al.</i> , 1949

developed (Halver¹) which contained only small traces of residual vitamin activity. This ration supplemented with crystalline vitamins proved successful in developing vitamin-deficiency syndromes in salmon for thiamin, riboflavin, pyridoxine, choline, pantothenic acid, inositol biotin, folic acid, and niacin (Halver,¹). Inconclusive results were obtained for vitamin B₁₂ and, under the experimental conditions, no need was demonstrated for para-aminobenzoic acid or ascorbic acid (Table 1). In addition to the vitamin-deficiency studies with salmon, a group of rainbow trout was reared through one reproductive cycle on the complete test diet to detect any deficiencies in the reproductive-vitamin content. Egg production and fertility proved normal in the mature fish. It should be valuable to use this diet to repeat previous tests for development of specific vitamin-deficiency syndromes in other species of trout and salmon.

HYPERVITAMINOSIS

Hypervitaminosis can be expected in fish as well as in other experimental animals when excessive quantities of certain oils or fats containing large amounts of the fat-soluble vitamins are fed. At least one report of hypervitaminosis A is present in the literature (Burrows *et al.*, 1952) when whale liver was used as a component of the diet. The diagnosis of the

¹ Halver, John E. 1953. A vitamin test diet for chinook salmon; the water-soluble vitamin requirements of chinook salmon. Ph.D. thesis; University of Washington. 82 pp.

typical hypervitaminosis A syndrome involving nervous disorders and eye inflammation was supported by the extremely high vitamin A content revealed by analysis of the diet. Similar results are possible if other rich sources of fat-soluble vitamins are included in the diet. The probability of developing hypervitaminosis of any of the water-soluble vitamins is remote, however, since they are so easily eliminated from the body that extremely high concentrations of the pure vitamin itself would be required before the hypervitaminosis syndrome would appear.

SUSCEPTIBILITY TO INFECTION

The state of nutrition of the individual determines to a large extent the resistance of the animal to bacterial infection. Although other factors play important roles in the production of antibodies in fishes (Snieszko, Wolf, this symposium) the defense mechanism of the animal demands the existence of adequate amounts of basic nutrients and precursors before these antibodies can be produced. If only one essential component is lacking or is present in inadequate amounts, the production of protective antibodies is severely hindered, allowing the bacterial infection to flourish. One of the first definite observations of lowered resistance in fish suffering a specific avitaminosis has recently been reported by Halver (1953). Further observations, although not detailed in this paper, indicated that folic acid played an extremely important role in resistance to infection. For 3 consecutive years, those lots of fish on folic acid-deficient diets were the first to exhibit myxobacterial infections, whereas other groups on the same water supply were affected only mildly. Of interest also is the role of inositol in "fin rot" and of biotin in "blue slime patch disease." Much work remains to be done before the role of vitamins in the prevention of disease can be defined, but current work in several laboratories should contribute to the solution of this problem in the near future. Now that experimental control of the nutritional components of diets is possible, intensive efforts can be directed toward determining the relationship between resistance to disease and nutritional balance.

GENERAL MALNUTRITION

In this review discussion of the immense amount of general data on practical fish diets will be omitted and emphasis placed on specific malnutrition syndromes.

One of the earliest observations on degeneration of the pancreas and surrounding tissue was recorded when excessive amounts of fat, or fat and carbohydrate were fed to trout (Hess, 1935) and chinook salmon (Donaldson, 1939).² The number of islets of Langerhans was severely reduced and fatty infiltration of the liver also occurred in some fish. Donaldson showed that cholesterol produced degeneration of the pancreatic tissue in

² Donaldson, Lauren R. 1939. Experimental studies in the nutrition of the chinook salmon with special reference to histological changes in the pancreas. Ph.D. thesis, University of Washington. 62 pp.

TABLE 2.—Vitamin-deficiency syndromes

[The numbers in parentheses refer to authorities listed in notes at bottom of table]

Vitamin deficiency	Signs of avitaminosis	
	In salmon and trout	In other animals
Thiamin	Poor appetite; muscle atrophy; convulsions prior to death; instability and loss of equilibrium; anorexia (1, 2, 3, 4). Generalized edema (4).	Poor appetite; muscle atrophy; convulsions in most acute stage; generalized edema; instability and loss of equilibrium; anorexia; brain lesions; degeneration of peripheral nerve fibers; impaired carbohydrate metabolism (6, 7).
Riboflavin	Corneal vascularization; cloudy lens, hemorrhagic eyes (1, 4). Photophobia; dim vision; incoordination; abnormal pigmentation of iris; striated constriction of abdominal wall; dark coloration; poor appetite (4).	Corneal vascularization; cloudy lens; hemorrhagic eyes; cataracts photophobia; dim vision; incoordination; abnormal pigmentation of iris; scleral congestion; cheilosis and angular stomatitis; impaired erythrocyte formation (6, 7).
Pyridoxine	Nervous disorders; epileptiform fits (1, 4). Light spots on liver (1). Hyperirritability; ataxia; anemia; loss of appetite; edema of peritoneal cavity; colorless serous fluid; spastic convulsions; blue-green coloration on back; <i>Post-mortem rigor mortis</i> occurs rapidly; rapid and gasping breathing; flexing of opercles (4).	Nervous disorders; epileptiform fits; hyperirritability; ataxia; anemia; loss of appetite; edema; symmetrical dermatosis; dermal lesions; iron deposition in liver; rise in serum iron (6, 7).
Pantothenic acid	Clubbed gills (1, 2, 3, 4, 5). Prostration; loss of appetite; necrosis and scarring; cellular atrophy; gills covered with exudate; sluggishness; general mumpy appearance (4, 5).	Prostration; loss of appetite; necrosis and scarring; cellular atrophy; spectacle alopecia; generalized scaling and dermatitis; diarrhea; hyperemia of intestine; myelin degeneration of nerves (6, 7).
Inositol	Poor growth; distended stomach; increased gastric emptying time (1, 4). Degenerated fin (1).	Poor growth; increased gastric emptying time; alopecia; nutritional encephalomalacia (6, 7).
Biotin	Loss of appetite; poor growth (1, 2, 4). Blue slime patch disease (2). Dark coloration; muscle atrophy; spastic convulsions; fragmentation of erythrocytes (4).	Loss of appetite poor growth; muscle atrophy; Seborrhic skin disease; generalized erythema; spastic gait; necrosis of fibers; increased sarcolemma (6, 7).
Folic acid	Poor growth; anemia (1, 4). Lethargy; fragility of caudal fin; dark coloration (4).	Poor growth; lethargy interspersed with convulsions; megaloblastic erythropoiesis; nutritional cytopenia; infarction of spleen (6, 7).
Choline	Poor growth; poor food conversion (1, 4). Hemorrhagic kidney and intestine (1). Aversion to food (4).	Poor growth; poor food conversion; aversion to food; fatty infiltration of liver; necrosis and scarring; reddish kidney; hemorrhagic eyes (6, 7).
Nicotinic acid	Loss of appetite; lesions in colon; jerky or difficult motion; weakness; edema of stomach and colon; muscle spasms while apparently resting (4). Swollen gills but not clubbed (1).	Loss of appetite; lesions in colon; jerky or spastic gait; weakness; pain; skin eruptions; edema of stomach and colon; anorexia; diarrhea; neurological lesions; fatty livers; vessel dilation (6, 7).

Vitamin B ₁₂	Poor appetite; erratic hemoglobin and erythrocyte counts; fragmentation of erythrocytes (4).	Pernicious anemia; macrocytic anemia; sprue; low or poor growth in young (6, 7).
p-Aminobenzoic acid	Poor appetite; light colored livers (1). No abnormal indications in growth, appetite, mortality (4).	Alopecia in rats and poor growth in chick (6, 7).
Ascorbic acid	Hemorrhagic liver, kidney, and intestine (1). No abnormal indication in growth, appetite, mortality (4).	Scurvy; capillary fragility; immature fibroblastic formation (6, 7).
"Cod Liver Oil"	Necrotic kidney (1).	

1 Observed by McLaren *et al.*, (1947) in rainbow trout

2 Observed by Phillips *et al.*, (1945-1949) in rainbow, brook, and brown trout

3 Observed by Wolf (1951) in rainbow trout

4 Observed by Halver (1953) in chinook salmon

5 Observed by Rucker, Johnson, and Kaydas (1952) in chinook salmon

6 Described in other animals by Hawk, Oser, and Summerson (1949)

7 Described in other animals by Wooster and Blanck (1949)

chinook salmon and other workers showed similar results when high cholesterol diets were fed to trout (Hewitt, 1937). Diets of high fat content or the lack of adequate exercise with normal or high food intake also caused destructive changes in the liver and pancreas (Hess, 1935). Choline proved an effective remedy for prevention of fatty degeneration of the liver and pancreas when the fat content of the diet components did not exceed 20 percent or 2 percent cholesterol (Donaldson, 1943).²

Studies on the absorption rate and utilization of carbohydrates in trout showed that, although the fish could absorb large quantities within a short period, the blood sugar level rose appreciably which indicated that trout are not physiologically able to handle carbohydrates at the same rate as higher vertebrates (Phillips, Tunison, and Brockway, 1948). Hyperglycemia also occurred in sockeye salmon, *Oncorhynchus nerka*, but was effectively reduced to normal glucose levels by administering cattle insulin. High glycogen livers and degenerated pancreatic tissue were again observed when diets of high carbohydrate content were used and a tolerance level of 9 percent of the diet was suggested. Reason dictates a level of not more than 20 percent of fats and carbohydrates combined in salmonid diets.

Since salmonid fish are carnivorous, excessive protein levels in the diets probably could not be obtained except in the experimental laboratory. Protein or amino-acid levels cannot be included in this review since the amino-acid requirement of fishes is not yet established. The higher the protein content of the diet the greater is the growth, provided all other essential factors are present.

As in most phases of fish nutrition, the determination of requirements of the inorganic elements has not been completed. Only iodine and sodium chloride have been shown to be essential for growth and metabolism, but the exact role of physiologically active salts has not been defined for fish. The prevention of goiters in fish in some iodine-deficient areas by the use

of iodine or iodine compounds was described previous to the period of this symposium. Under normal conditions, the inorganic components of the diet may be ignored for most diet ingredients contain sufficient amounts of physiologically active salts except in highly purified experimental diets or in waters of low inorganic salts. With the advent of experimental diets containing salt-free components and the possible use of new water-deionizing equipment, an entire new field of exploration of the specific role of the elements and their salts in enzyme kinetics and intermediary metabolism lies open.

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TUMORS AND OTHER ATYPICAL CELL GROWTHS IN TEMPERATE FRESHWATER FISHES OF NORTH AMERICA

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ABSTRACT

This report deals with any abnormal tissue, the growth of which exceeds and is uncoordinated with that of the normal tissue. Included in this category are the neoplasia (benign and cancerous), non-functional hyperplasias, cellular hypertrophy as well as other atypical cell growths. The following topics are discussed with special reference to the temperate freshwater fishes of North America: papillomas, hyperplastic epidermal diseases (including fish pox), parasitic and neoplastic adenomas, carcinomas (including thyroid tumors), fibromas, fibrosarcomas, myxomas, leiomyomas, rhabdomyomas, granulomas, lymphosarcomas, pigment-cell tumors, neurofibromas, neurilemmomas, hamartomas, and teratomas.

The role of such factors as physical and chemical irritants, nutrition, endocrine dysfunction, heredity, embryonic disturbances, and such infectious agents as viruses, bacteria, mycotic organisms, and protozoans in the production of these abnormalities is given or suggested.

With the exception of certain tumors, our knowledge concerning neoplasms in fishes in general is extremely limited, and very few contributions have been made by American fishery biologists. It is suggested that a greater effort be made to recognize these diseases, especially tumors which appear spontaneously in large populations of fishes.

INTRODUCTION

The pathological conditions considered in this paper include any abnormal mass of tissue, the growth of which exceeds and is uncoordinated with that of normal tissue. Included are hyperplasias, neoplasias and other tumorous growths.

The term *hyperplasia* refers to an increase in the amount of cellular elements in a specific tissue in excess of those normally present. The epidermis of fishes is usually composed of relatively few layers of epithelial cells but under the action of certain stimuli may be increased many times (e.g., in fish pox). We do not include hyperplasias which involve normal proliferation of cells as a compensatory response to loss of tissue or to increased functional demand, as the development of "pearl" organs in certain minnows during breeding season. We do include such proliferation, however, if the growth continues in an excessive manner after cessation of the stimulus, or if the stimulus persists so as to cause an exceptional amount of growth.

When the tissue retains its property of persistent growth independently of the stimulus which started it, the growth must be considered a *neoplasm*.

According to Willis (1948), "The most distinctive character of neoplastic proliferation is that it is uncoordinated, independent of the structural and functional pattern of the organism, and indefinitely progressive. In this it differs fundamentally from reparative growth, hyperplastic growth and growth of malformation, in all of which the cellular multiplication is limited in amount and duration in accordance with more or less specifiable factors."

Neoplasias may also involve some permanent cellular changes. If the cells tend to revert to a more primitive and undifferentiated form, or if there is a change in a cell by which it becomes incapable of attaining perfect structure and function, then the growth is said to be an *anaplasia*. The change of one kind of tissue into another, or the production of tissue by cells which normally produce tissue of another sort is called *metaplasia*. It should be emphasized, however, that tumors of a given cell type may vary greatly in the degree of differentiation. In many thyroid tumors in fishes there is little or no change from the normal histological pattern but under certain conditions the follicles continue to proliferate, causing considerable destruction of the surrounding tissues.

The classification of tumors in fishes, as in other animals, is based on histogenesis. They are classified on the basic tissue of origin, such as epithelial, mesenchymal, hemopoietic, neural, . . . For a review of tumors in cold-blooded animals, the reader is referred to the excellent monograph by Schlumberger and Lucké (1948). Many of the tumors reported in the literature have been analyzed and reclassified by these authors, and all the available information brought up to date. Their paper forms a basis for a better understanding of neoplasia in fishes. Table 1 lists the tumors reported in North American temperate fresh-water fishes. The tumors listed in Table 2 are found in European fresh-water fishes that are also indigenous to North America. The lists, however, do not include the hyperplasias and tumors caused by infectious agents which are also discussed in this paper. Table 3 is a list of North American fresh-water fishes in which lymphocystis disease (cell hypertrophy) has been reported.

The writer (Nigrelli, 1938) has previously reviewed some of the types of tumors and their probable causes in aquarium fishes. It is the purpose of this paper to discuss tumors and other atypical cell growths (*e.g.*, lymphocystis tumors) in temperate fresh-water fishes under both natural and captive conditions and to indicate, where possible, the importance of such factors as physical and chemical irritants, nutrition, endocrine dysfunction, heredity, embryonic disturbances, viruses, bacteria, mycotic organisms, and protozoans, in the production of these abnormalities.

TUMORS OF EPITHELIAL TISSUE

The benign epithelial tumors are referred to as papillomas and adenomas, whereas the malignant growths are called carcinomas. Terms such as epithelioma, epidermoid carcinoma and adenocarcinoma indicate variations of structure as to kind and degree of differentiation.

PAPILLOMAS

These vary in appearance from small, round, warty growths to large cauliflower-like masses. Histologically, the tumors show an extreme hyperplasia of the epidermis and the underlying (corial) connective tissue, with a typical papillary arrangement.

Although tumors of this type have been reported in a number of fresh-water fishes from Europe and other countries, only one case has been found in North America. Two large papillomas were described by Schlumberger and Lucké (1948) in the ventral part of the tail of an 8-year-old white sucker, *Catostomus commersoni*, caught in a Wisconsin lake.

It has been suggested that the occurrence of multiple wart-like papillomas in several fish of a population living in the same environment may be due to an infectious agent, and because of the presence of cellular inclusions in some of the growths, a virus has been suspected (see Nigrelli, 1952a). It is possible, however, that the tumors may be of traumatic origin. Thus, the writer observed the development of a fibro-epithelial papilloma in the snout of a rainbow trout, *Salmo gairdneri*, which was the site of a hemorrhagic lesion, the result of an injury caused by the fish bumping into the sides of the aquarium.

HYPERPLASTIC EPITHELIAL DISEASES

Many papillary-like growths in fishes are associated with various parasites and can only be distinguished from true neoplasias by histological and cytological examination. Some of these are discussed below.

Fish Pox (Hyperplastic Epidermal Disease).—Pox disease, sometimes called hyperplastic epidermal disease, cutaneous warts, or epithelioma papillosum, is characterized by numerous milky white or gray, flat, raised or papillary-like growths on the skin, fins, and eyes. Microscopically there is an exceptional amount of hyperplasia of the epidermis. According to Schlumberger and Lucké (1948), these growths cannot be sharply distinguished from true neoplasia, except that the lesions of pox usually regress and may eventually disappear.

Hyperplastic epidermal disease is common in carp, other cyprinids (tench, ides, and bream), pike, perch, and smelts. According to Plehn (1924), carp-pox was first recorded in 1563 by Gessner, the great naturalist of the 14th century. Since then, the disease has been reported in carp from all parts of Europe and Asia but to date it has not been found in North America in this species. The writer (1948b), however, has reported pox-like lesions in about 200 bluegills (*Lepomis macrochirus*) from Connecticut (Figs. 1 and 2). No doubt this disease must be much more widespread in North American fresh-water fishes.

In Europe, epidemics of fish pox often occur in large populations and, although the disease is not usually lethal, it makes the fish unsightly and therefore unmarketable. The lesions usually appear in the spring, persist during summer and fall, and gradually disappear in winter. Occasionally

the growths may remain with little evidence of regression for at least 2 years. This cycle, together with the recurrence of the disease in the same fish species in the same lake, pond or stream from year to year, has led many European investigators to suspect an infectious agent. Although such parasites as *Ichthyophthirius multifiliis* (a holotrich ciliate), certain Myxosporidia, Microsporidia, argulids, and copepods can induce a mild hyperplasia of the epidermis, the epidemiological, histological, and cytological evidence strongly suggests that a virus is the cause of fish pox (Nigrelli, 1952b). The recent electron-microscopic studies by Roegner-Aust and Schleich (1951) and by Roegner-Aust (1953) demonstrating virus-like particles, measuring 70-220 millimicrons, in diseased cells and in particulates of such cells tend to support the virus hypothesis for this disease.

The lack of critical evidence of a virus has led certain other European investigators to suggest that the disease may be the result of avitaminoses or calcium deficiency, or that it may be environmentally induced. Schäperclaus (1941), who discussed these factors, believed that heredity plays the most important role in carp pox. There are some striking similarities between fish pox and the gill disease of trout described by Wolf (1945) in which a hyperplasia of the gill epithelium results from the combined action of vitamin deficiency and chemical irritation.

Epidermal Hyperplasia Associated with Protozoan Parasites.—Hyperplasia of the epidermis may be caused by many parasites to which fish are susceptible. The pustules seen in infections with *Ichthyophthirius multifiliis* histologically show a simple hyperplasia of the epithelial cells around the ciliate. The tissue is often thrown into papillary folds but little or no connective tissue is developed.

Tissue growths associated with Myxosporidia are more striking, sometimes presenting tumors that are difficult to distinguish from true neoplasia. Thus, Plehn (1924) described a tumor in a small *Leuciscus* sp. as a papillary adenocytoma caused by *Myxobolus piriformis*. A papillary cystic disease affecting the barbels of brown bullhead, *Ameiurus nebulosus*, was found to be caused by the myxosporidian *Henneguya ameiurensis* (Nigrelli and Smith, 1940). The parasites developed in the dermal connective tissue, where they formed large cystic cavities. The epithelium overlying the cysts was considerably thickened, giving the lesion a papillary or warty appearance. A tumor (Nigrelli, 1948a) in the snout of a redhorse sucker, *Moxostoma aureolum*, was found associated with the myxosporidian *Myxobolus moxostomi*. Histologically, the epidermis overlying the parasitic cysts was exceptionally hypertrophied and the hyperplasia consisted mainly of prickle cells.

Gill Disease (Hyperplasia of Gill Epithelium).—Gill disease is characterized by an extreme hyperplasia of the gill epithelium and sometimes by a fusion of adjacent lamellae through cellular proliferation. According to Plehn (1924), epidemics of this disease have been reported in Denmark, England, and Italy in Salmonidae, Clupeidae and Cyprinidae. The epidemiology is similar to that of fish pox, and this fact has led some investigators to suspect a similar etiology. Plehn, however, indicated that the condition

is caused by abnormal chemical factors. This hypothesis is partly supported by the experimental evidence obtained by Wolf (1945) for gill disease in hatchery-reared fingerling trout in New York State. Wolf, and others (Tunison, *et al*, 1944; Rucker, Harlan and Kaydas, 1952), have shown that fish placed on a pantothenic-acid-free diet developed the gill lesions ("clubbing") when treated fish were exposed to conditions in which metabolic fish wastes were more highly concentrated. According to Davis (1926, 1927, 1953), similar lesions were found associated with some unknown species of myxobacteria in fingerling trout, largemouth bass, (*Micropterus salmoides*), smallmouth bass, (*M. dolomieu*), and blackcrappie, (*Pomoxis nigromaculatus*). Davis (1953) distinguished the two diseases with similar lesions as "bacterial gill disease" and "dietary gill disease."

Hyperplasia of the respiratory epithelium may also occur in response to infection and infestation with animal parasites. Kudo (1919) described such a growth in the gills of a channel catfish, *Ictalurus punctatus*, infected with the myxosporidian *Henneguya exilis*. The writer has noted similar proliferation and fusion of respiratory elements in fishes infested with ergasilid copepods, *Ichthyophthirius*, and/or with various species of monogenetic trematodes.

ADENOMA

This is a benign epithelial tumor with a gland-like structure. Only three cases have been reported thus far in North American temperate freshwater fishes. Nigrelli (1943) reported an adenoma in the kidney of a northern pike, *Esox lucius*, which was associated with a lymphosarcoma. This neoplasm should be reclassified as a lymphadenoma since there was an extensive proliferation of the lymphoid elements as well as the uriniferous tubules. Adenomas of the ovary and kidney have been described by Bieseke (1943) and by Schlumberger and Lucké (1948) in a goldfish *Carassius auratus*, and catfish, respectively. The catfish tumor occurred in a specimen which was also affected with an epidermoid carcinoma of the lips.

The writer recently received from Dr. S. F. Snieszko, U. S. Fish and Wildlife Service, an enlarged liver (30 grams) taken from a female rainbow trout. The tumor was identified as a hepatoma (Fig. 3). The diseased fish liver was sent to Dr. Snieszko by Mr. Robert Piper, Newville, Pa. In the covering letter, Mr. Piper stated, "This morning we found another female rainbow trout and it had the swollen liver I described to you on my visit to Leetown." This would indicate that hepatomas, and possibly carcinomas, may be relatively common in this strain of rainbow trout. The relationship of parasites, haematochromatosis (haemosiderin), and cirrhosis to liver tumors should be investigated. These factors are often present in fish and may be regarded as predisposing conditions.

HYPERPLASIA OF EPITHELIAL ELEMENTS OF GLANDS AND OTHER ORGANS ASSOCIATED WITH PARASITES

It is well known that parasites can be the etiological agents in certain tumors of mammals and in other animals (Ewing, 1940; Craig and Faust, 1940; Willis, 1948). In coccidiosis of the liver of rabbits, the parasites

excite a tumor-like proliferation of the bile duct. As pointed out by Ewing, the process is strictly dependent upon the presence of the *Coccidia*, and the tumor regresses when the parasites are removed. Because it regresses, the growth is not a true tumor. Nevertheless, it has some of the characteristics of a neoplasm, even though they are dependent on the parasitic irritant. The same principle holds true for all tumors and hyperplasias in fishes caused by parasites.

Information is limited concerning the exact pathological effects of fish parasites. In the majority of fishes, the tissue reactions are indicated by focal accumulation of histiocytes (macrophages), granulocytes, plasma cells, haemosiderin, and ceratoid elements. Atrophy, hyalin degeneration and other necrobiotic changes are often present in the immediate regions of the infection. Frequently the host reaction to the parasites is manifested by mild inflammation, simple cyst formation, or by an extensive fibrosis, bordering on a true fibroma. Occasionally, there may also be a decided hyperplasia of the epithelial elements, often resembling cystadenoma, adenoma, and adenocarcinoma in parasitic infections in the liver, kidney, gonads, intestine, and gall and urinary bladder. Such growths are particularly evident in gall-bladder infections by *Myxosporidia* (Kudo, 1919, 1930; Fantham, and Richardson, 1940).

EPITHELIOMA—EPIDERMOID CARCINOMA

Epitheliomas differ from papillomas in that the epithelial cells tend to invade the corium and other underlying structures of the skin, thus showing some degree of malignancy. Histologically, fish epitheliomas resemble the mammalian epidermoid carcinomas in that they consist of pavement epithelium which forms solid downward growths (pegs) from the basal layer of the epidermis.

In Europe such tumors have been reported in carp and goldfish (Table 2). McFarland (1901) was the first to report an epidermoid carcinoma in a North American fresh-water fish, the white catfish (*Ictalurus catus*). More recently, Lucké and Schlumberger (1941) and Schlumberger and Lucké (1948) described such tumors in the lips, oral mucosa, and dental plates of 266 mature brown bullheads from the Delaware and Schuylkill Rivers, in or near Philadelphia. The writer has two specimens with similar lip tumors which were collected by Mr. Roland Smith, New Jersey Conservation Department, from Strawbridge Pond (Burlington County) and Lenape Lake (Atlantic County), both of which drain into the Delaware River (Fig. 4). The appearance of these tumors in a number of individuals of a single species from one general area (Delaware River and its drainage system) should lead one to suspect, environmental, hereditary, or infectious agents as the cause.

ADENOCARCINOMAS AND THYROID TUMORS

Carcinoma is a malignant growth of epithelial cells which tend to infiltrate the surrounding tissues and give rise to metastases. Adenocarcinoma is a malignant tumor of gland-cell origin. Tumors of the latter type are the predominant cancers in man.

With the exception of thyroid tumors, there is a dearth of information concerning adenocarcinomas in fishes. The only cases in fresh-water fishes were reported by Schmey (1911) and by Plehn (1924) in the kidney of the eel, *Anguilla anguilla*, by Haddow and Blake (1933) in the ovary of a northern pike, and by Nigrelli and Gordon (1951) in the pancreas of a hybrid platyfish, *Platyocilus maculatus* x *Xiphophorus helleri*. There is some question whether the ovarian tumor reported by Biesele (1943) in the goldfish, is an adenoma or adenocarcinoma. The same may hold true for the hepatomas recorded in trout.

The writer recently received from Mr. Roland Smith, a 3-year-old female carp (*Cyprinus carpio*), measuring 37.5 centimeters, with a massive tumor of the stomach (Figs. 5 and 6). The growth was identified as an adenocarcinoma of hepatic origin. This is the second case of a stomach carcinoma. Previously, we have reported a carcinoma-like tumor in the stomach of a deep-sea fish (Nigrelli, 1947a).

It should be emphasized that the incidence of tumors of soft tissues and organs must be higher than indicated by the record. The lack of information is no doubt related to the fact that they usually present no external manifestations and are thus generally overlooked.

Thyroid tumors, however, are relatively common in fishes, especially in the salmonoids (see Tables 1 and 2). The only case of a thyroid tumor in a non-salmonoid temperate fresh-water fish previously reported was described by Marine and Lenhart (1910b) in a northern pike. The writer has in his possession photographs of a thyroid tumor in a goldfish (Fig. 7) which were taken by the late G. M. Smith, Yale University.

Several thousand cases of thyroid tumors in salmonoids have been reported since they were first described in 1883. Many of these growths represent simple hyperplasia (see Robertson and Chaney, 1953) and goiters but there can be no doubt that some of them are true adenomas and adenocarcinomas. The writer (1952a) has taken the view expressed by Willis (1948) with regard to human thyroid tumors, namely, that no clear separation of epithelial hyperplasia, benign and malignant thyroid tumors is possible. The gland in teleosts is a non-encapsulated structure which when unduly stimulated produces a progressive growth that is capable of infiltrating surrounding tissues, causing considerable destruction. Histologically, many such growths are of simple hyperplasia. In others, the picture may be somewhat similar to the interacinous adenomas in human goiters reported by Ewing (1940). In bony fishes, interacinous adenomas may represent a true neoplastic process even though there may be little change in the histological character of the tissue. Where anaplastic and metaplastic changes are evident, the thyroid tumors in such fishes must be considered as malignant adenocarcinomas.

As in human thyroid tumors, the exact cause of the growths in fishes has not been determined, even though some can be made to regress by the addition of iodine to the diet. Jaboulay (1908), Gaylord and Marsh (1914), and Nigrelli (1952a) have suggested that factors other than iodine deficiency in the diet may be responsible for thyroid tumors in

fishes. The studies of Gorbman and Gordan (1951) and by Berg, and Gordon (1953) in Mexican killifishes indicate that heredity may play an important role.

TUMORS OF NON-HEMOPOIETIC MESENCHYMAL TISSUES

The neoplasias included in this category arise in connective, skeletal, vascular, meningeal, and muscular tissues. The benign tumors are called fibroma, myxoma, lipoma, chondroma, osteoma, angioma (haemangioma, lymphangioma), meningioma, leiomyoma, and rhabdomyoma. Malignant tumors are referred to as "sarcoma," often with a prefix corresponding to the benign counterpart, *e.g.*, fibrosarcoma.

Except for meningiomas, tumors of the above classes have been reported in fishes. As stated by Schlumberger and Lucké (1948), "The intermutability of mesenchymal tissues, and the complexity of tumors arising from these tissues, render their classification difficult." For this reason, many of the tumors in fishes have been designated simply as sarcomas since the exact histogenesis has not been determined.

FIBROMAS, FIBROSARCOMAS, AND "SARCOMAS"

Fibromas are characterized by extensive proliferation of connective tissue. They are usually composed of collagenous fibers with the consistency of the tumor (hard or soft) related to the degree of vascularity and edema, to the amount of chondrification and ossification, and to the absence or presence of mucoid degeneration or cyst formation. The presence of pleomorphic, closely packed cells embedded in a fibrillar substance is distinctive of fibrosarcoma.

Fibromas have been reported by various investigators in northern pike, carp, goldfish and lake trout (see Table 1 and 2). The tumors reported in the carp were found in the body cavity, whereas in other species, the tumors were external, arising in the skin, subcutaneous tissue, and musculature. The only cases of simple fibroma in North American temperate freshwater fishes were reported by Kreyberg (1937) in a brown trout, *Salmo trutta*, and by Nigrelli (1951) in a rainbow trout. An eastern chain pickerel, *Esox niger*, recently sent to the writer by Mr. Roland Smith, was found to have a massive fibroma (approximately 2.5 centimeters in diameter) in the lower jaw (Fig. 8). Microscopically, the tumor was composed of dense figrous tissue arranged in whorls, and, although the growth was poorly vascularized, very little necrosis was evident.

Tumors for which the exact histogenesis could not be established but which contained pleomorphic sarcomatous-like elements and very little fibrous tissue were classified as "sarcomas" by Schlumberger and Lucké (1948). Of particular interest are the subcutaneous sarcomatous-like growths reported in goldfish by Roffo (1924), Montpellier and Dieuzeide (1932), and Lucké, Schlumberger, and Breedis (1948). Each author described tumors which appeared spontaneously in a number of fish kept in the same aquarium or pool, thus indicating an infectious process or

TABLE 1.—*Tumors in North American temperate freshwater fishes*

[Number after species indicates cases reported. Common names in this table conform to the Society's official list and are not necessarily the same as given by the original authors]

Type of tumor and species of fish	Site of tumor	Author
Papilloma		
White sucker (1)	Skin, near tail	Schlumberger, and Lucké, 1948
Fibro-epithelial papilloma		
Rainbow trout (1)	Snout	Nigrelli, this paper
Adenoma		
Brown bullhead (1)	Kidney	Schlumberger, and Lucké, 1948
Northern pike (1)	Lipsdo.	Nigrelli, 1943
Goldfish (1)	Ovary	Bieseke, 1943
Rainbow trout (1)	Liver	Nigrelli, this paper
Epithelioma ¹		
White catfish (1)	Lips	McFarland, 1901
Brown bullhead (166)	Lips and mouth	Lucké, and Schlumberger, 1941
do. (100)	do.	Schlumberger, and Lucké, 1948
Adenocarcinoma		
Carp (1)	Stomach	Nigrelli, this paper
Thyroid tumors		
Salmonoid fishes (several thousands)		
Brown trout	Thyroid	Smith, 1909
Brook trout	do.	Marine, and Lenhart, 1910a, 1910b, 1911
Rainbow trout	do.	Marine, 1914
Sebago salmon	do.	Gaylord, and Marsh, 1914
Brown trout	do.	do.
Atlantic salmon	do.	do.
Lake trout	do.	do.
Pink salmon	do.	do.
Coho salmon	do.	do.
Chinook salmon	do.	do.
Sockeye salmon	do.	do.
Sunapee trout	do.	do.
Lake whitefish	do.	do.
Non-salmonoid fishes		
Northern pike (1)	do.	Marine, and Lenhart, 1910b
Goldfish (1)	do.	Nigrelli, this paper

Fibroma			
Brown trout (1)	Abdominal	Kreyberg, 1937	
Rainbow trout (1)	Jaw	Nigrelli, 1951	
Chain pickerel (1)	do.	Nigrelli, this paper	
Sarcoma, unclassified²			
Goldfish (1)	Skin	Schamberg, and Lucké, 1922	
do. (1)	Dorsal fin	Dominguez, 1928	
do. (30)	Subcutaneous	Lucké, Schlumberger, and Breedis, 1948	
Myxoma			
Brown trout (3)	Skin	Nigrelli, 1940	
Rainbow trout (1)	do.	do.	
Bluegill (2)	do.	do.	
Largemouth bass (2)	do.	do.	
Smallmouth bass (4)	do.	Nigrelli, 1943	
Rock bass (1)	do.	Schlumberger, and Lucké, 1948	
Goldfish (several)	do.		
Leiomyoma			
Goldfish (1)	Cutaneous	Nigrelli, this paper	
Rhabdomyoma			
Cutthroat trout (1)	Trunk	Adami, 1908	
Lymphosarcoma			
Northern pike (1)	Dorsal fin	Ohlmacher, 1898	
Atlantic salmon (1)	Kidney	Haddow, and Blake, 1933	
Northern pike (12)	do.	Nigrelli, 1947b	
Muskellunge (1)	Trunk	Nigrelli, 1952b	
Neurilemmoma and neurofibroma			
Brook trout (25)	Mesentery and pancreas	Young, and Olafson, 1944	
Brown trout (1)	do.	do.	
Goldfish ³ (14)	Cutaneous, eyes, branchial and peritoneal cavities	Schlumberger, 1949	
do. (53)	Cutaneous and eye	Schlumberger, 1951, 1952	
do. (2)		Nigrelli, this paper	

¹ Epidermoid carcinoma² Fibrosarcoma³ Originally called leiomyoma

Table 2.—*Tumors in European temperate freshwater fishes which also occur in North America*
 [Number after tumor type indicates cases. Common names in this table conform to the Society's official list and are not necessarily the same as given by the original authors]

Type of tumor	Site of tumor	Author
Tumors in northern pike (<i>Esox lucius</i>)		
Adenocarcinoma (1)	Ovary	Haddow, and Blake, 1933
Fibroma ¹ (1)	Muscle	Plehn, 1906
Sarcoma ² (1)	Kidney	Plehn, 1909, 1924
Osteoma (1)	Jaw	Bland-Sutton, 1885
do. (1)	Vertebra	Plehn, 1906
Osteosarcoma (1)	Anal fin	Wahlgren, 1876
Lipoma (1)	Subcutaneous	Bergman, 1922
Lymphosarcoma (1)	Subcutaneous	Haddow, and Blake, 1933
Tumors in carp (<i>Cyprinus carpio</i>)		
Epithelioma ³ (1)	Skin	Dauwe, and Pennemann, 1904
do. (1)	Not mentioned	Bashford, Murray, and Craner, 1905
do. (1)	Fins and operculum	Fiebiger, 1909a
Fibroma (1)	Peritoneum	Crisp, 1854
do. (1)	do.	Gervais, 1876
do. (1)	Mesentery	Ronca, 1914
Osteochondroma (1)	Skull	Fiebiger, 1909b
Tumors in goldfish (<i>Carassius</i> spp.)		
Papilloma (2)	Fins	Sagawa, 1925
Epithelioma (1)	Bladder	Plehn, 1909
Fibroma (1)	Orbit	Guglianetti, 1910
do. ⁴ (1)	Subcutaneous	Wago, 1922
do. ⁵ (1)	Skin	Sagawa, 1925
do. (1)	Trunk muscle	Eguichi, and Oota, 1926
Sarcoma unclassified (1)	Dorsal fin	Bland-Sutton, 1885
do. (1)	Subcutaneous	Semer, 1888
do. (1)	do.	Johnstone, 1923
do. (7)	do.	Roffo, 1924
do. (5)	do.	Montpellier, 1933
Neurofibroma (1)	Skin	Picchi, 1933
Lymphosarcoma	Kidney	Plehn, 1924

Tumors in trout and salmon (*Salmonidae*)

Tumors in trout and salmon (<i>Salmonidae</i>)		Thomas, 1932b
Papilloma, brow trout (1)	Skin	Plehn, 1909
Adenoma	Liver	Haddow, and Blake, 1933
do., rainbow trout (1)	do.	Thomas, 1931a
Cystadenoma, cutthroat trout (1)	Intestine	Plehn, 1912
Dental plate tumor, trout sp. (1)	Dental plates	Bonnet, 1883
Thyroid tumors, brown trout (3,000)	Thyroid	Plehn, 1902
do., rainbow trout (3)	do.	Gilruth, 1902
do., Atlantic salmon (1)	do.	do.
do., trout spp. (several)	do.	Pick, 1905
do., trout spp. (6)	do.	Jaboulay, 1908
do., rainbow trout (many)	do.	Leger, 1925
do., trout sp. (1)	do.	Peyron, and Thomas, 1930
do., salmon sp. (1)	do.	do.
Fibroma, brown trout	Subcutaneous	Eberth, 1878
Sarcoma, unclassified, brook trout (1)	Trunk muscle	Plehn, 1906
do., chum salmon (1)	Body wall	Kazama, 1922
do., rainbow trout (1)	Not given	Leger, 1925
do., chum salmon (2)	Body wall	Takahashi, 1929
do., pink salmon (1)	do.	do.
Leiomyoma, rainbow trout (1)	Stomach wall	Plehn, 1906
do., trout, <i>Salmo carpio</i> (1)	Pylorus	Pesce, 1907
Osteoma, brook trout (1)	Fin rays	Thomas, 1932a
Erythrophoroma, trout sp. (1)	Skin	Thomas, 1931b
Tumors of threespine sticklebacks (<i>Gasterosteus aculeatus</i>)		
Haemangioma (3)	Subcutaneous and head	Plehn, 1906
do. (1)	Iris	Johnstone, 1915

¹ Lipofibroma² Probably lymphosarcoma³ Epidermoid carcinoma⁴ Myxoma?⁵ Multiple tumors, maybe neurofibroma⁶ Epithelial origin⁷ American spp. sent to Pick⁸ May be a lymphosarcoma

presence of external carcinogenic factors. Lucké Schlumberger, and Breedis reported 30 cases from pools in Atlantic City and in the Philadelphia Zoo. A topographical analysis showed that most of the tumors occurred in the left lateral side of the body, the majority in the trunk region. Histologically, the growths were found in the corium and resembled fibromas, fibrosarcomas, and occasionally myxomas, but because of the small amount of fiber formation, a purely fibroblastic origin was considered doubtful. These investigators concluded that hereditary factors probably played no part in the etiology of the disease but found some indirect evidence that the tumor-inducing factors were either transmissible or environmental. Exposure of healthy fish to a presumably tumor-inducing environment led to the tentative conclusion that the carcinogenic factors were either weak or slow in their action.

FIBROSIS ASSOCIATED WITH PARASITES

Many fish parasites are capable of eliciting a connective-tissue response. The degree of proliferation depends upon the species of parasite and the intensity of the infection or infestation. Connective-tissue cyst formation is a characteristic host response to larval nematodes, certain lernaeid copepods, larval cestodes, and to the metacercarial stage of many of the digenetic trematodes. The development of such cysts, however, is more striking in certain types of myxosporidiosis, especially in infections of the subcutaneous tissues. Diffuse infections in this area often result in extensive development of collagenous fibers, producing massive tumors resembling true neoplasia (Nigrelli and Smith, 1938).

Nigrelli (1948a) suggested that intracellular and intercellular myxosporidians elaborate enzymes (hyaluronidase) or other chemical substances that may be the stimuli responsible for cellular hypertrophy, hyperplasia, and even metaplasia often noted in these infections. The latter condition, which is characteristic of many malignant neoplasias, was observed by Kudo (1929). He noted and described the transformation of subcutaneous connective tissue into "epithelioid" elements in areas of infection with *Thelohanellus notatus* in the bluntnose minnow, *Hyborthynchus notatus*.

MYXOMATAS

These are tumors of loose connective tissue with branched cells interspersed with mucoid material. Certain mesenchymal tumors in goldfish reported by Lucké, Schlumberger, and Breedis (1948) were regarded as tumors of this type by Schlumberger and Lucké (1948). Nigrelli (1940, 1943) recorded 13 cases of myxomas in six species of North American temperate fresh-water fishes (Table 1). In each instance, the growth was a grayish elevated, translucent patch in the dorso-lateral region of the body. Histologically, the growth consisted of stellate-shaped cells forming a loose network of tissue. Whether or not these growths are true neoplasms remains to be determined.

The history of the disease in the rock bass *Ambloplites rupestris*, may indicate the origin of the myxomatous growths in these fishes. The rock bass was heavily parasitized with *Chilodonella* (a holotrich ciliate) which caused an extensive production of mucus, nearly covering the entire surface of the body. When the infection subsided, the translucent mucoid growth developed.

CHONDROMAS AND OSTEOMAS

Tumors involving the skeletal structures have not been reported in North American fresh-water fishes. Several cases of neoplasias of various parts of the endoskeleton, fins, jaws, opercula, and skull, have been described, however, in other fresh-water fishes. Thus, chondromas or enchondromas have been reported in the crucian carp, *Carassius carassius*, by Muslow (1915; see Plehn, 1924), in the barbels, *Barbus fluviatilis*, by Surbeck (1917), in the elritze (*Phoxinus laevis*) by André (1927) and in the jewelfish, *Hemichromis bimaculatus* by Nigrelli and Gordon (1946). The tumor in the jewelfish occurred in the operculum; the reader is referred to this paper for a detailed histological description of an osteochondroma in a fish.

The writer (1943, 1951) recorded an osteoma in a rainbow trout but upon reexamination the growth was found to be a simple exostosis, the result of an injury to the lower jaw. Osteomas and osteosarcomas, however, have been reported in several species of fresh-water fishes (Table 2).

Tumors of meristic skeletal structures are probably much more common in freshwater fishes than has been suspected. Many tumors and other abnormal growths involving the vertebrae and their associated parts are no doubt overlooked. Thus, by intensive search, Takahashi (1929) found 102 cases of bone tumors in the haemal spines of the 6th-8th vertebrae in *Pagrus major*, a Pacific sparid. Whether or not these are true osteomas or normal hyperostosis in aging fish remains to be determined (Breder, 1952).

LIPOMAS

Lipodystrophy occurs frequently in fishes, especially under hatchery and aquarium conditions. Lipomas, however, are extremely rare. Schlumberger and Lucké (1948) recorded only seven cases in the literature, one of which was described by Bergman (1922) from the subcutaneous region in the trunk of a northern pike which measured 60 centimeters in length. The tumor mass weighed 160 grams and microscopically consisted mainly of typical fat cells.

LEIOMYOMAS AND RHABDOMYOMAS

Neoplasms of the musculature are also rare in fishes. Leiomyomas or smooth-muscle tumors have been found in the stomach wall of an 8-year-old rainbow trout by Plehn (1906) and in another species of trout (*Salmo carpio*?) by Pesce (1907; see Thomas, 1931a). The cutaneous leiomyomas

reported by Schlumberger (1949) in 3-4 percent of the goldfish population from a pond in Ohio, are now considered as neurilemmomas with characteristics of the Antoni type-A tissue (Schlumberger, 1952). Because of the complexity of mesenchymal tumors in fishes, it is difficult to determine the exact histogenesis of some of the growths of such an origin. The Antoni type-A neurilemmomas are partly characterized by palisade arrangement of the nuclei. It should be emphasized, however, that not all tissues showing this nuclear pattern should be classified as neural in origin since other tumorous tissues may show a superficial palisading of nuclei. Such a condition was seen in two leiomyomas found in the subcutaneous tissue of a ribbontail goldfish (Fig. 9) sent to the writer by the late Dr. Nelson Gowanloch, Louisiana Conservation Department, who found the specimen in a pool in New Orleans. Histologically, the tumor was composed of sheets of tissue with closely packed fibrillar-like elements with deeply staining nuclei in which the shape (oval, flat, elongate) conformed to the outline of the cells. There was some indication that the leiomyoma arose from the smooth-muscle layer of the small blood vessels in the corium.

The only tumor of striated muscle in a fish from North American waters was reported by Adami (1908). The growth occurred in the trunk musculature of a cutthroat trout, *Salmo clarki*, and was specifically identified as a giant-cell rhabdomyosarcoma.

HAEMANGIOMAS

These are benign neoplasms consisting of newly formed blood vessels. No growths of this type have been recorded in North American fishes although they have been described by Plehn (1906) and Johnstone (1915) as occurring comparatively frequently in European sticklebacks, *Gasterosteus aculeatus*.

CELLULAR HYPERTROPHY

Cellular hypertrophy or cell enlargement appears to be a characteristic reaction in fishes to intracellular and intercellular myxosporidians and microsporidians and to viruses. Such atypical growths are included in this part of the discussion because the cells (fibroblasts, osteoblasts, chondroblasts and polyblasts) are derived from non-hemopoietic mesenchymal tissues, and under certain conditions produce massive tumor-like lesions. Classical examples of such growths are the well-known lymphocystis elements and the so-called *Glugea* "cysts", both of which are extremely enlarged and transformed cells, presumably resulting from the presence of the intracellular parasites.

Glugea Cysts

One of the more striking examples of cellular hypertrophy in fishes was described by Weissenberg (1921) in European sticklebacks, *Gasterosteus aculeatus* and *G. pungitius*, infected with the microsporidian *Glugea anomala* (Class Sporozoa, Subclass Cnidosporidia). The schizont invades a

connective tissue cell where it undergoes a series of divisions, terminating in sporogony. During this development, the cell enlarges and becomes transformed into a cyst having a thick hyalin membrane. These parasitic cysts occur in the connective tissue of the corium, cornea, intestine, liver, and gonads. External cysts may occur in the head, trunk, fins, and branchial chambers. In the skin, the infected cell, or *Glugea* "cysts," may develop from an original size of 10-15 microns to a diameter of 2 to 4 millimeters (Kudo, 1924).

Similar "cysts" were reported by Weissenberg (1911) in European smelt, *Osmerus eperlanus*, infected with *Glugea hertwigi*. This microsporidian is also responsible for frequent epidemics in smelt, *Osmerus mordax*, in North America (Fantham, Porter and Richardson, 1941; Haley, 1952).

LYMPHOCYSTIS DISEASE OR VIRAL LYMPHOCYSTIOSIS

Lymphocystiosis is an infectious but usually non-fatal disease of marine and fresh-water fishes in which the affected cells reach gigantic size. The history of this interesting abnormality, first reported in European flounders in 1874, has been outlined by Nigrelli and Smith (1939) and by Nigrelli (1952b). Table 3 lists the species in which the disease has been reported in North America. It will be noted that the condition is evidently common in the Percidae and Centrarchidae. The incidence in walleye *Stizostedion vitreum*, and in black crappie and white crappie, *Pomoxis annularis*, is comparatively high in some localities, and the disease is, therefore, of some economic importance. The growths found in the skin make the fish so unsightly that affected individuals are culled and discarded by lake fishermen.

The lesions are grayfish, flat, nodular or tumorous growths having a granular appearance. This appearance is due to the presence of numerous white, spherical, or ovoid bodies which may measure up to several millimeters in diameter. In living fish these bodies, so-called lymphocystis cells, at times may be seen to drop off like so many tapioca beads. In preserved specimens, the cells are easily dislodged since they are not cemented to adjacent cells or neighboring tissue.

Lymphocystis cells are supposedly enlarged fibroblasts, osteoblasts, chondroblasts, or polyblasts (histiocytes). The transformed cells show a striking resemblance to eggs or ergasilid copepods which are usually present in large numbers in the gills of fishes affected with this disease (Nigrelli, 1950). At one time or another, lymphocystis cells have been considered to be fish eggs, sporozoan parasites, and eggs of metazoan parasites. The diseased cells occur primarily in the lymph spaces of the skin, but they also have been reported in the spleen, gonads, heart, gills, and stomach. It has never been established whether they represent metastasized elements or are cells which have developed *in situ*. The lymphocystis cell in the skin may be surrounded by lymphocytes, macrophages (histiocytes), melanophores, and collagenous fibers. In certain fishes (e.g., walleye), there may be a considerable proliferation of connective tissue, resulting in massive fibroma-

TABLE 3.—*Lymphocystis* disease in North American temperate freshwater fishes

[Number after species indicates number of fish unless otherwise designated. Common names in this table conform to the Society's official list and are not necessarily the same as given by the original authors]

Species of fish	Locality	Author
Walleye	Lake Minocqua, Wis.	Mavor, and Feinberg, 1918
do.	Lake Erie	Hyde, 1937
do. (60)	Lake Erie and Lake Huron	Weissenberg, 1939
do. (5 percent)	Saginaw Bay, Lake Huron	do.
do. (7)	Lake Erie	Bangham, and Hunter, 1939
do. (6)	Illinois	Nigrelli, 1943
do.	Rolling Stone Lake, Wis.	Bangham, 1946
do.	Upper Turtle and Teal Lake, Wis.	Fischthal, 1947
do.	Lake Onego, N.Y.	Walker, 1947
Sauger	Lake Erie	Bangham, and Hunter, 1939
Orangespotted sunfish	New York Aquarium	Nigrelli, 1943
Pumpkinseed	Philadelphia Aquarium	Weissenberg, 1945
do.	New York Aquarium	Nigrelli, 1952b
Bluegill	Philadelphia Aquarium	Weissenberg, 1945
Green sunfish x bluebill hybrid	U. S. Fish and Wildlife Service, Dexter, N.M.	do.
Longear sunfish	St. Francis River, Greenville, Mo.	do.
Largemouth bass	Half Moon Pond, St. Mary's, Ohio	do.
do.	Huron River, Wayne Co., Mich.	do.
do.	Schuykill River, Philadelphia, Pa.	do.
Spotted bass	Wheeler Reservoir, Ohio	do.
Yellow perch	Lake Erie	Walker, 1947
Black crappie	Illinois River	Weissenberg, 1945
do.	Schuykill River, Philadelphia, Pa.	do.
White crappie	Illinois River valley	Hansen, 1951
do. (1.4 percent)	Senachwine Lake, Ill.	do.
do. (19.5 percent)	Lake Chataqua	do.

like tumors (Fig. 10). This pathological state is characteristic of a host reaction to parasitic infection or infestation. Evidently, lymphocystis cells are either parasitic elements or represent host cells in which the character has been altered to such an extent that they behave as parasites or as foreign bodies.

Cytologically, each lymphocystis cell is enclosed in a thick hyalin capsule and contains an enlarged nucleus with one or several nucleoli, and a densely granular or vacuolated cytoplasm with basophilic, Feulgen-positive inclusions. Sometimes the entire cytoplasm reacts to Feulgen much in the same manner as the yolk of egg cells. Weissenberg (1939), and more recently Alexandrowicz (1951), traced the development of the inclusions from a single Guarneri-like body in the young lymphocystis cell. The inclusions were described as increasing in size concomitantly with the enlargement of the diseased cell. Eventually, the basophilic material develops into a perinuclear network. According to Weissenberg (1951a), who first proposed the virus hypothesis for lymphocystiosis, the network contains osmiophilic granular structures which represent stages in the developmental cycle of the lymphocystis virus. The virus particles are believed to accumulate in large numbers in the mature lymphocystis cells and to be liberated when the tumor cells disintegrate in the water after extrusion or after death of the fish. For an excellent description and interpretation of the histological and cytological features of the lymphocystis cell in various stages of development, the reader is referred to the paper by Alexandrowicz (1951).

In temperate fresh-water fishes, lymphocystis disease usually appears in the spring, reaches a maximum development during summer and gradually disappears in fall and winter. The lesions, however, may appear and disappear suddenly (within a few days) or may persist for a year or more. The fact that not all fish of a species in one population are susceptible during epidemics indicates that at least some individuals are resistant or are immune, probably as a result of a previous infection.

Successful intraspecific, interspecific and interordinal transmission of the disease was accomplished by Rasin (1927, 1928), Weissenberg (1939, 1945, 1951a, b) and by Nigrelli (1952b). These investigators reported that healthy intact and bruised fish become infected after exposure to water containing an emulsion of lymphocystis material, after intraperitoneal and intradermal injection of emulsified preparations, after exposure to water containing the filtrate of lymphocystis material, and after transplantation of bits of lymphocystis tumor tissue. For the first time in the long history of lymphocystiosis, the filterability of the lymphocystis virus was demonstrated by Weissenberg (1951c). He reported a positive interordinal transmission from walleye to killifish, *Fundulus heteroclitus*, with material filtered through a Chamberland-Pasteur filter L-5.

TUMORS OF HEMOPOIETIC TISSUES LYMPHOSARCOMAS

In the classification of human tumors, such neoplasias as lymphosarcomas, lymphatic leukemias, and Hodgkin's disease are considered as

growths arising from hemopoietic tissues. No cases of leukemia or tumor resembling Hodgkin's disease have been described in fishes. A number of papers on lymphosarcomas, however, have been published and this subject was reviewed by the writer (Nigrelli, 1947b, 1952b).

Enough evidence has been accumulated to indicate that lymphosarcomas may be widespread in the Esocidae during certain seasons of the year and that the disease may be infectious, probably caused by a virus or rickettsial-like organism. In the northern pike, the tumors were found in the hemopoietic tissue of the kidneys and metastatic lesions were observed in the liver and spleen. The origin of the cutaneous "lymphosarcomas" in the muskellunge, *Esox masquinongy*, (Fig. 11) remains to be determined. Fish often respond to cutaneous infections by an influx of large numbers of histiocytes (macrophages or polyblasts). It is possible that under certain conditions a hyperplasia of these elements may occur, producing a histiocytoma or a growth which would have the appearance of a round-cell sarcoma or a lymphosarcoma. It would be biologically and oncologically important to determine the exact histogenesis, incidence, and transmissibility of this disease in the Esocidae and related species.

GRANULOMAS

Granuloma is a tumor which may result from bacterial, fungal, protozoan, and other parasites. It is most frequently associated with mycotic infections, where granulation tissue, consisting of plasma cells, leucocytes, giant cells, and fibroblasts, form a nodule around either the entire mycelium or a single hypha. The growths may become malignant if a fibrosarcomatous-like tumor develops. The literature relating to this subject in fish was reviewed by Ermin (1952) who also described in detail a granuloma in a Turkish species. The only known instance of such a growth in a North American fresh-water form is the mycetoma reported by Walker (1951) in the head of a single fingerling landlocked salmon from an Idaho hatchery. The granuloma was a large, lobed, clearly defined growth which extended from the dorso-lateral skin to the midline both above and below the brain. The septate mycelium formed centers of whorls or granuloma. The latter was composed mainly of fibroblastic cells and some epithelioid or multinucleated giant cells. The growth involved the skin, periosteum, and the membranes of the brain. Tumors of this kind are no doubt more common than indicated by this single case.

TUMORS OF NEURAL TISSUES

Tumors of neural origin have been reported as neurofibromas, neurilemmomas and neurogangliomas. Neurofibroma is a connective-tissue tumor of the nerve-fiber fascicle, originating by proliferation of the perineurium and endoneurium; neurilemmoma, also called Schwannoma and neurinoma, is a tumor of the nerve sheath (neurilemma); neuroganglioma (neuroma), which is rare in fishes, is a tumor of the nerve cell proper.

Neurofibroma and neurilemmomas appear to be relatively common in

certain fishes. There is some doubt that the neurilemmomas reported by Young and Olafson (1944) in brook trout, *Salvelinus fontinalis*, from a New York hatchery are true neoplasias. The leiomyomas in the skin of goldfish described by Schlumberger (1949) have been reclassified as neurilemmomas by him (1952). This investigator (Schlumberger, 1951, 1952) reported neurilemmomas and neurofibromas in a relatively large number of goldfish and suggested that they are probably hereditary. A survey (Schlumberger, 1952) of goldfish in a lagoon in Cleveland showed that 8 to 10 percent of the fish had one or more tumors. Both sexes were represented and fish were estimated to be between 5 and 8 years old. The incidence did not change in 6 years of observation. Furthermore, the record showed that no goldfish were introduced to the lagoon since it was originally stocked in 1926. With the exception of one fish with an intra-abdominal and another with a branchial neurilemmoma, the tumors were widely distributed over the surface of the body. One hundred and forty-four tumors were found in 53 fish and seven cases were histologically malignant. The assumption that the tumor were probably hereditary is partly based on the fact that both tumor-bearing and otherwise normal fish were often affected with anomalies that included polycystic kidneys, keratoconus, and buphthalmos. Schlumberger (1952) stated "The frequency of congenital lesions served to emphasize the fact that the fish were an isolated population probably subjected to considerable inbreeding and therefore had some genetic homogeneity." He further suggested that these tumors show a striking comparison with von Recklinghausen's neurofibromatosis in man for which a hereditary factor has also been suggested.

Tumors of neural-tissue origin are no doubt common in goldfish throughout the world. Some of those reported as fibromas and fibrosarcomas may fall into this category. The writer has in his possession two goldfish, one from a pool in the San Diego Zoo and another from Atlantic City, with neurofibromas involving the trunk, operculum, and eye (Fig. 12). These examples would suggest that such tumors occur in this species from other parts of the United States. An intensive search would probably give a more accurate figure on the incidence.

TUMORS OF PIGMENT CELLS

The pigment cells in fishes are melanophores, xanthophores, and erythrophores (allophores). Together with the non-pigmented elements, guano-phores and iridiocytes, such cells make up the pigmentary system in these animals. Tumors composed of these cells that have been described in fishes are termed melanomas, xanthophoromas, guanophoromas, and iridiocytomas. Melanomas of the skin of fishes are the most common type and also the most malignant of the pigment-cell neoplasia. Iridiocytomas are the rarest.¹

Pigment-cell tumors, especially melanomas have been reported more

¹Through personal correspondence with Dr. E. S. Schmidt of the Biologisches Forschungsinstitut at Hamburg, Germany, the writer has been made aware of an apparently malignant, transplantable iridiocytoma in certain albino strains of Siamese fighting fish, *Betta splendens*.

often in marine fishes than in fresh-water species (Nigrelli and Gordon, 1944; Schlumberger and Lucké, 1948). For fresh-water species, the studies on hereditary melanomas in xiphophorine fishes and their hybrids by Gordon (1951) are outstanding. These fishes are also susceptible to tumors involving the xanthophores, erythrophores, mixed pigment cells (xantho-erythrophores), and combination of these with melanomas (Nigrelli, Jakowska, and Gordon, 1951).

Thomas (1931b) recorded the only pigment-cell tumor in a temperate freshwater fish—an erythrophoroma in the skin of an unnamed species of European trout. The growth was orange and had infiltrated the anal fin. A similarly colored tumor mass in the peritoneal wall of the stomach was suspected as a metastatic lesion.

The black tumors reported by Osburn (1925) in brown bullheads from a lake in Falmouth, Massachusetts, may or may not be melanomas. These growths, which also have been observed by Vinal Edwards and Henry David Thoreau in brown bullheads from this locality and in the Concord and Assobet Rivers, were found in various parts of the skin and fins and in the lips, mouth, esophagus, and gills. Because of the presence of numerous bacteria, these lesions are not considered as neoplastic. Examination of Osburn's Figures 5 and 6, however, shows a highly thickened corium and somewhat hypertrophied epithelium. His Figure 6 is characteristic of certain melanomas observed by the writer in other fishes. It is possible that these tumors in the catfish may be melanotic and that the bacteria may be secondary invaders. Further studies are needed to determine the exact nature of these apparently common tumors in catfish from the above localities.

HAMARTOMAS AND TERATOMAS

Hamartomas are non-neoplastic tumors or tumor-like nodules which arise as the result of embryological defects. They are abnormal formations of tissues and may replace or displace the normal structure. Thus, Schlumberger and Lucké (1948) referred to the tumor of the pineal organ in the mackerel, *Scomber scomber*, reported by Charlton (1929) as a hamartoma. Charlton found that the area in which the pineal body should have been located was occupied by a series of epithelial folds. In several places, bead-like masses of hyalin cartilage were found in the abnormal tissue. This author considered the growth as a chondro-epithelioma. The tumor destroyed or replaced the pineal body but had caused little damage to the rest of the brain.

Teratomas, on the other hand, are true tumors or neoplasias characterized by the presence of embryonic remains of another individual. The condition reflects some degree of uncoordinated growth. Teratomas do not include, however, such abnormalities as fully formed, sometimes functional, supernumerary structures (*e.g.*, fins, gills, . . .). An extensive bibliography on teratology of fishes was given by Gemmill (1912) who also described and illustrated a large number of such abnormalities in trout and salmon, some of which may be true teratomas.

Hamartomas and teratomas are included in this discussion because fishery biologists are well aware of some of the gross manifestations of these atypical growths, especially since they commonly occur in hatchery fishes. Studies relating to this subject in fishes have been neglected in recent years by biologists and oncologists.

NEED FOR RESEARCH ON TUMORS AND OTHER GROWTHS

It is apparent from this report that little is known about tumors and other atypical cell growths in temperate fresh-water fishes of North America. Excluding the salmonoid fishes with abnormal thyroid growths, only 17 species have been thus far recorded with neoplasias. No doubt the incidence and number of species with tumors is much higher. That fish with abnormal growths are just as common as one might expect them to be in a given population of a fresh-water species is indicated by the studies of Lucké and Schlumberger (1941) and Schlumberger and Lucké (1948) who, with the aid of fishery biologists from Pennsylvania, obtained 266 brown bullheads with lip cancers from the Delaware River drainage system. One hundred and sixty-six were found in only 2 years. It would be valuable for cancer specialists to determine whether such tumorous catfish occur in other parts of North America. This information would indicate whether or not the carcinogenic factors for this neoplasm are limited to the northeastern United States.

Two other diseases that should be studied more intensively, partly because a virus is suspected, are fish pox (hyperplastic epidermal disease) and lymphosarcoma. From casual conversations with fishery biologists it is the writer's impression that fish pox has been observed in species other than the bluegill from Connecticut (Nigrelli, 1948b). It is surprising that this disease has not been found in carp in North America, since epidemics of carp pox have occurred in Europe and Asia since the Middle Ages. The reports of lymphosarcomas in North American and European Esocidae by Ohlmacher (1898), Haddow and Blake (1933), and Nigrelli (1947b, 1952b) show that this neoplastia is also of common occurrence. Lymphosarcomas in early stages of development are probably overlooked since they may arise in the kidney, an important lymphopoietic organ in teleosts. Only by careful examination of this and other lymphoid tissues (thymus, spleen, intestinal mucosa) can the true incidence of this disease be determined.

The relatively high incidence of epidermoid carcinomas in the lips of bullheads (Lucké and Schlumberger, 1941; Schlumberger and Lucké, 1948) and the numerous cutaneous tumors of mesenchymal and neural origin in goldfish (Lucké, Schlumberger, and Breedis, 1948; Schlumberger, 1951, 1952) would lead one to suspect that the cause may be infectious, environmental or hereditary.

The dearth of information on tumors in temperate fresh-water fishes of North America can be partly attributed to the lack of interest by fishery biologists, especially among those in charge of lake and stream surveys, who fail to forward diseased specimens to interested pathologists. Since the

writer's appeal to those attending this symposium in Milwaukee, a number of fishes with important neoplasms have been received from various parts of the country. Among them was a stomach carcinoma in a carp and a hepatoma in a hatchery-reared rainbow trout. These are recorded for the first time in this paper. It is our prediction that a more intensive search will reveal that the incidence of the two types of cancers in each of these species will be relatively high.

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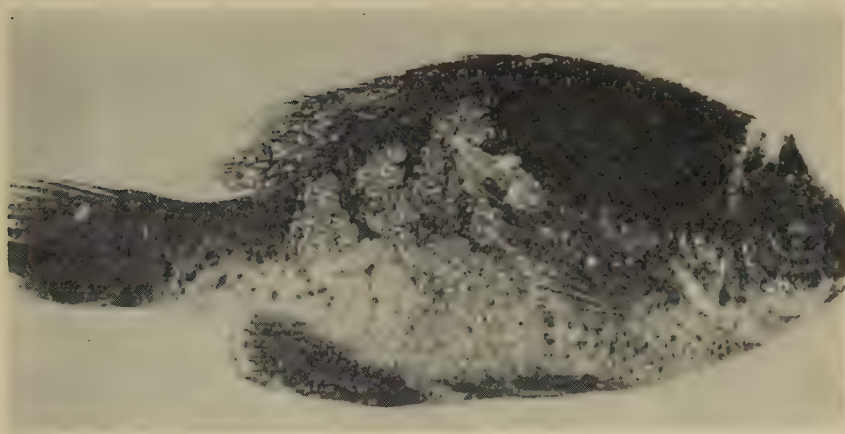


FIGURE 1.—Bluegill with hyperplastic epidermal disease, also called fish pox.

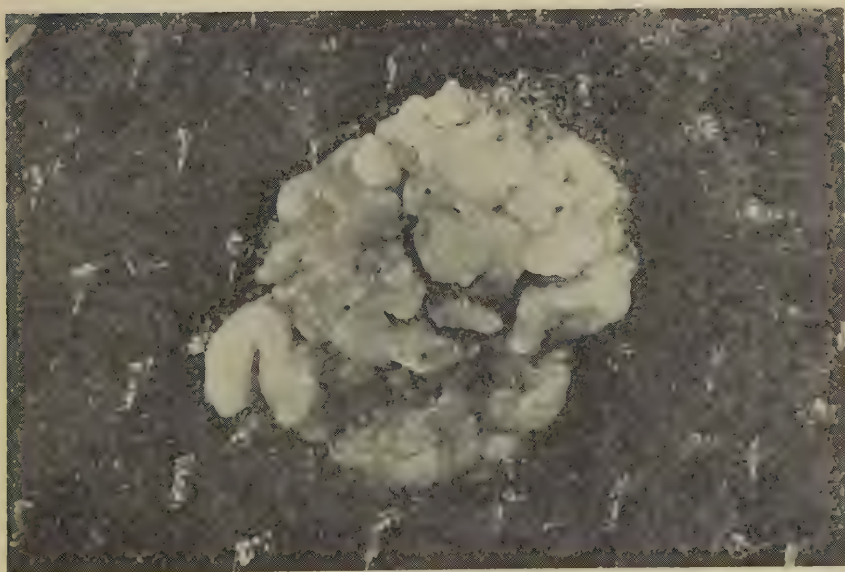


FIGURE 2.—Bluegill pox lesion showing papillary arrangement.

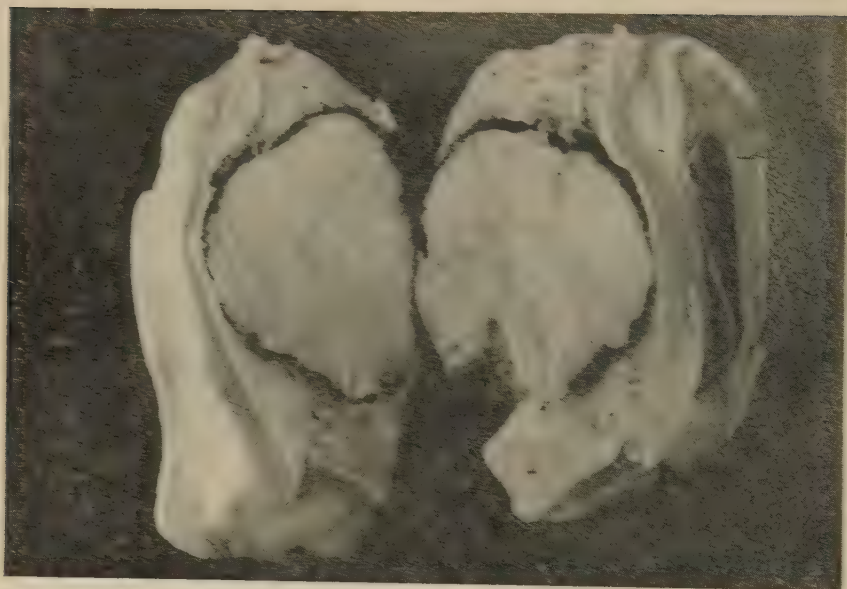


FIGURE 3.—Liver tumor (hepatoma) in rainbow trout. Submitted by Dr. S. F. Snieszko, U. S. Fish and Wildlife Service.

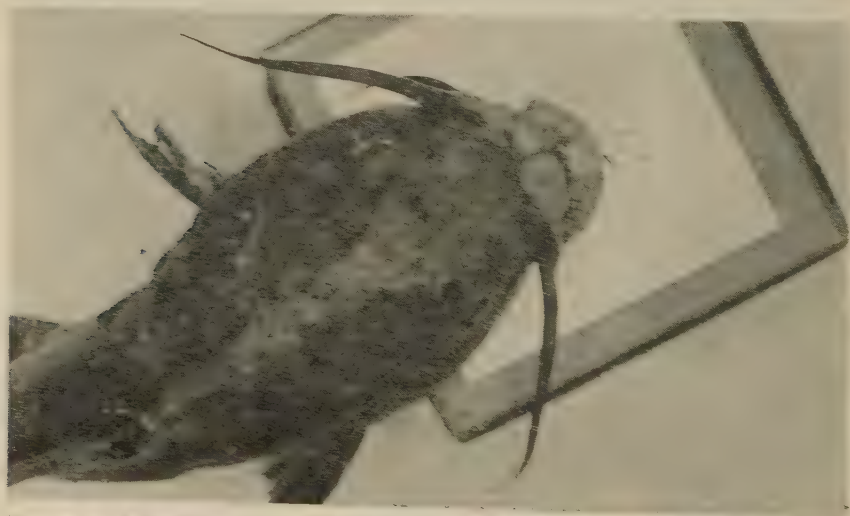


FIGURE 4.—Epithelioma (epidermoid carcinoma) in lips of brown bullhead. Submitted by Mr. Roland Smith, New Jersey State Conservation Department.



FIGURE 5. Female carp showing external manifestation of stomach tumor. Photograph by Roland Smith.



FIGURE 6. Stomach mass, weighing 250 grams, which was identified as an adenocarcinoma of hepatic origin.

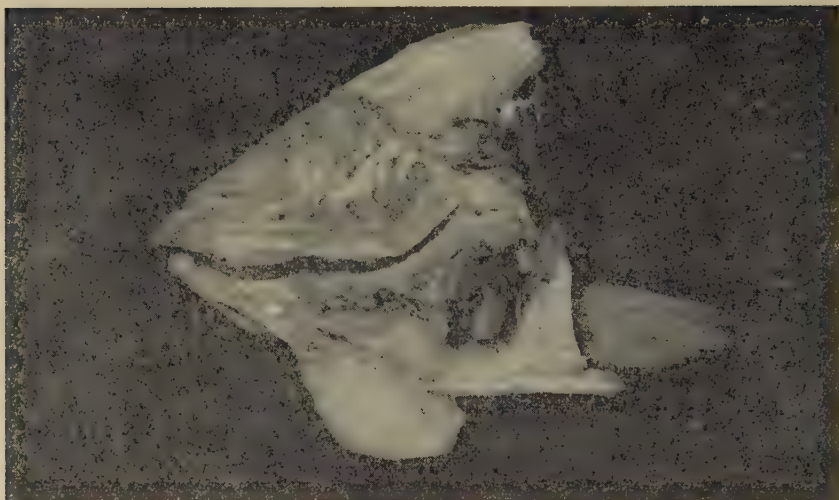


FIGURE 7.—Sagittal section through head of goldfish with thyroid tumor. Photograph by the late Dr. G. M. Smith, Yale Medical School.

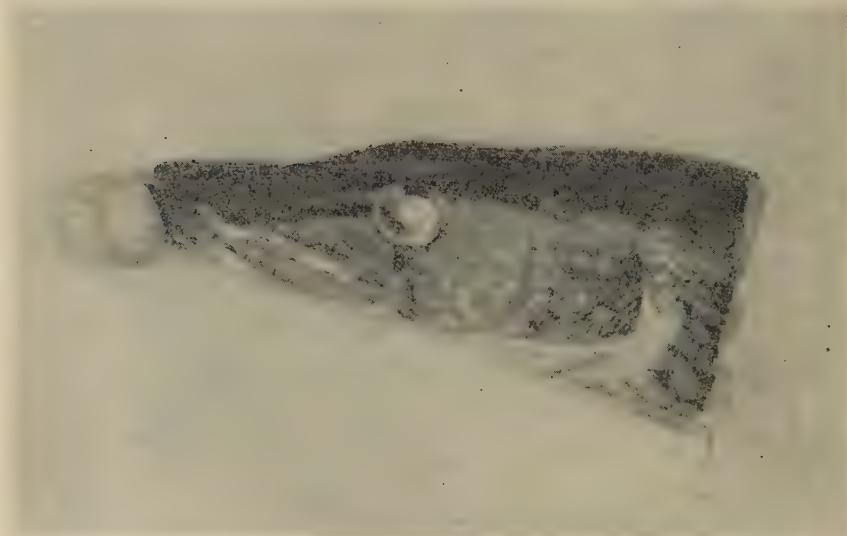


FIGURE 8.—Fibroma in lip of chain pickerel. Submitted by Roland Smith.



FIGURE 9.—Leiomyoma in ribbontail goldfish.

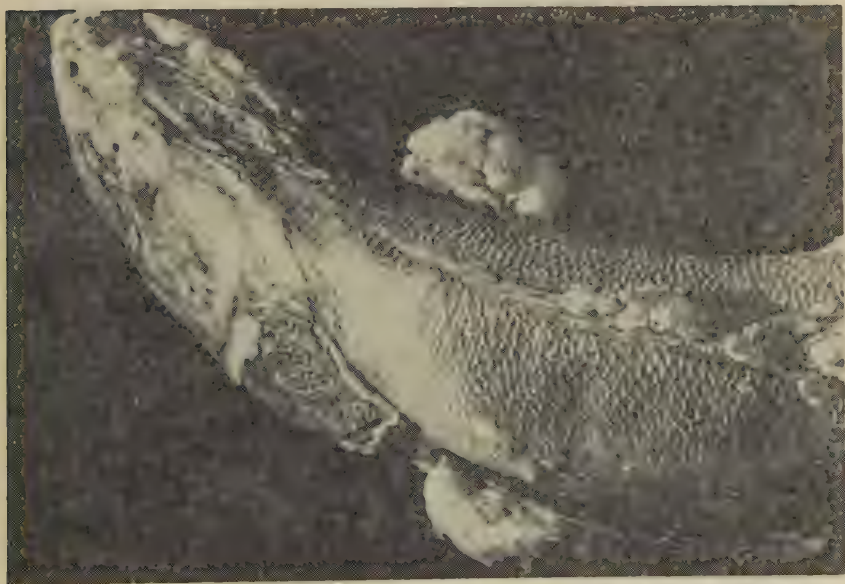


FIGURE 10.—Lymphocystis tumors in walleye from Illinois. Submitted by Dr. Louis A. Krumholz.



FIGURE 11.—Lymphocarcinoma-like mass in region of pelvic fins in a muskellunge. Material and photograph by Dr. A. M. Fabis, Ontario Research Foundation.



FIGURE 12.—Neurofibroma in goldfish. Photograph by Mr. S. C. Dunton, New York Zoological Society.

INFECTIOUS DISEASES OF PACIFIC SALMON

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ABSTRACT

Investigations on infectious diseases of Pacific salmon due to micro-organisms other than viruses are reviewed. The etiological agents include trematodes, fungi, protozoa and bacteria. Bacteria have been found to be the most important agents of disease in the several species of Pacific salmon. Kidney disease, due to a small, unnamed Gram-positive diplobacillus, causes serious mortalities in young salmon reared in hatcheries. The disease has also been found in wild fish. Aquatic myxobacteria are important agents of disease both in the hatchery and in the natural habitat. One of the myxobacteria, *Chondrococcus columnaris*, causes disease at relatively high water temperatures. The problem of the taxonomy of this organism is discussed. Another myxobacterium, *Cytophaga psychrophila*, has been found responsible for epizootics in coho salmon at lower water temperatures, i.e., in the range of 40° to 55° F. In outbreaks of gill disease in young salmon, myxobacteria of several kinds have been implicated.

A variety of bacteria has been found responsible for outbreaks of disease in salmon in sea water. The most important of these is a species of *Vibrio*. Tuberculosis has been found in adult chinook salmon and the evidence indicates that the disease was contracted at sea.

INTRODUCTION

Five species of salmon occur in the waters of the Northeast Pacific ocean. These salmon are distinct from the Atlantic salmon and from true trout, although they are included with these in the family Salmonidae. The Pacific salmon are anadromous fish and all belong to the genus *Oncorhynchus*. The names of the five species are chinook (*O. tshawytscha*), coho (*O. kisutch*), sockeye (*O. nerka*), chum (*O. keta*), and pink salmon (*O. gorbuscha*). The eggs develop in fresh water and the young remain there for periods ranging from a short time to a year or two before going to sea. After a year or more in salt water, the adult salmon return to fresh water

to spawn. Consequently, it is logical to expect that there may be different infectious agents which attack salmon in the two habitats. Furthermore, it might be expected that the diseases of salmon in the fresh-water habitat might be transmissible to other salmonid fishes. In general, this has proved to be the case. A good deal of attention has been paid to infectious diseases of salmon in fresh water. So far, much less has been done in the study of diseases of salmon in the marine habitat; greater difficulties are inherent in the study of these diseases and the investigations carried out have been largely exploratory in character.

The infectious agents responsible for mortalities in salmon in fresh water include trematodes, protozoa, fungi, bacteria, and viruses. Viruses are considered in another paper in this symposium, hence no references will be made to them here.

TREMATODE PARASITES

Trematodes are of little consequence as a cause of fatal disease in salmon in the Pacific Northwest. The monogenetic trematode, *Gyrodactylus* sp., occurs occasionally in hatcheries but is easily controlled by treatment with formalin. The metacercarial stage of the fluke, *Trogloitrema salmincola*, is occasionally found in considerable numbers in salmon in areas where the snail, *Goniobasis plicifera*, is found. Bennington¹ has expressed the opinion that heavy infestations of the metacercariae can cause death of young salmon. The fluke, *T. salmincola*, is generally considered responsible for the transmission of the etiological agent of salmon disease in dogs. This agent has been classified among the Rickettsia by Cordy and Gorham (1950). There is a possible relationship between the etiologic agent responsible for salmon poisoning in dogs and that responsible for kidney disease in young salmon (Earp, Ellis and Ordal, 1953).

PROTOZOAN PARASITES

The external protozoan parasites, *Costia*, *Trichodina*, and *Ichthyophthirius* are responsible for low grade infections and may cause mild epizootics in young salmon in hatcheries. This type of infection is characterized by the fish flashing and darting about, and the fish may show an increase in mucus secretion, or in the case of *Ichthyophthirius* show small white spots in the skin. These diseases are of little consequence in that they are readily controlled by formalin treatment, although *Ichthyophthirius* may cause some difficulty as it has a stage imbedded in the skin of the fish.

A stalked ciliate which has not yet been classified has been associated with some mortalities in young salmon. This protozoan was not affected by formalin in the concentrations normally employed, but was easily controlled by the use of acetic acid or pyridylmercuric acetate (Burrows and Palmer, 1949). Since prophylaxis with pyridylmercuric acetate is used routinely for gill disease, the parasite no longer presents a problem.

¹ Bennington, Elwin Everett 1951. The life history of the salmon poisoning fluke *Trogloitrema salmincola* (Chapin). 50 pp. Ph.D. thesis, Oregon State College.

The intestinal flagellate, *Octomitus salmonis*, occurs occasionally in stocks of fish, but it is difficult to decide that it is actually a serious cause of mortalities. Following standard practice, calomel is often used as the therapeutic agent in outbreaks of octomitiasis, but in our experience, it is difficult to conclude that the therapy is of any particular value. Unless other agents are present, the losses presumably due to octomitiasis resolve in time even without treatment.

Myxosporidia have been observed in salmon but no severe epizootics have been recorded. A member of the genus, *Ceratomyxa*, was found in rainbow trout from Lacamas Lake in Washington.² The legal sized fish developed severe infections by this myxosporidian about six weeks after they had been planted in the lake. Similar fish held at the hatchery and those planted in other lakes did not develop this infection. Very large numbers of the rainbow trout were found dead and dying in the lake and were found to be infested with tremendous numbers of *Ceratomyxa* sp. in the liver, spleen, kidney and intestine. A catfish taken at the same time had a large furuncle containing huge numbers of similar myxosporidia, but none were noted in the internal organs. It was reported by M. Smith³ that a considerable mortality had occurred earlier in the catfish present in the lake, but microscopic observations were not made. It is possible that the surviving catfish present in the lake served as a source of the myxosporidia responsible for the mortality in the rainbow trout. Noble (1950) reported that a myxosporidium, *Ceratomyxa shasta*, was responsible for high mortalities in rainbow trout at the Crystal Lake hatchery in California. Possibly organisms of this type are more prevalent than has heretofore been realized, and they may well be responsible for fatal disease in salmon.

PARASITIC FUNGI

An interesting micro-organism has been isolated from a serious outbreak of disease in trout, but it is also pathogenic to salmon under experimental conditions (Rucker and Gustafson, 1953). This organism generally occurs as a sphere varying from 10 microns to 80 microns in diameter, affecting all organs and tissues of the fish. The organism has been identified as a species of *Ichthyosporidium*, although differing from previously described species. Morphologically it most closely resembles *I. hoferi*, which has been held responsible for a disease in herring in sea water (Scattergood, 1948).

Saprolegnia parasitica is the commonest of the pathogenic or parasitic fungi in fishes. Infections with this fungus can be expected whenever fish are debilitated from other causes. Our experience is that any extensive outbreak of *Saprolegnia* is a sequel to debilitation from some other infection and occasionally follows the use of an inadequate diet.

An unnamed fungus, temporarily classified in the order Sphaeropsidales of the Fungi Imperfecti, has been found responsible for disease in salmon.⁴ This fungus was found in the extreme posterior part of the intestine of pink,

² Rucker, R. R., D. Lavere and E. J. Ordal. Unpublished data.

³ Personal communication.

⁴ Rucker, R. R. Unpublished data.

sockeye and chinook salmon fingerlings. The populations of fish observed with this infection had just started feeding but still had considerable yolk material present. Necrosis of the posterior gut and musculature was associated with this infection. Outbreaks of this disease have not been widespread in character; but when it has occurred, the populations of fish affected suffered catastrophic mortalities.

BACTERIAL DISEASES

A large share of our attention has been given to the study of bacterial diseases of salmon. Outbreaks of furunculosis, caused by *Bacterium salmonicida*, occur occasionally in stocks of young salmon. Though there have been reports of the occurrence of disastrous losses due to furunculosis in the past years, we have never observed such an outbreak. The disease in salmon responds readily to sulfamerazine or sulfamethazine. Apparently the disease in salmon is often self-limiting, for in a number of instances the disease has disappeared from control ponds which were not given sulfonamide therapy.

A variety of pseudomonads have been isolated during the course of outbreaks of disease in young salmon. *Pseudomonas fluorescens* or related varieties are most often found. Strains of *P. hydrophila* have been found, but less frequently. Although the pseudomonads isolated usually kill fish upon injection, they have never been found as primary agents responsible for an epizootic in salmon. The evidence indicates that pseudomonads should be included among the agents responsible for mortalities in young salmon debilitated from other causes. In one outbreak of disease in sockeye salmon fingerlings, a streptomycete and a concomitant pseudomonad were isolated from a number of moribund fish (Rucker, 1949). The organism was named *Streptomyces salmonicida* and was shown to be pathogenic. On inoculation characteristic necrosis occurred. This is interesting since no type of actinomycosis had previously been reported in fish. The pseudomonad was also pathogenic and when injected experimentally into fish caused peritonitis and the development of small areas of erythema on the surfaces of the fish.

External ulcers occur in some outbreaks of disease in young salmon, and in our experience, myxobacteria are characteristically involved. In no case has *Hemophilus piscium* been isolated, although the methods recommended by Snieszko, Griffin and Friddle (1950) and Snieszko (1952) have been used. *H. piscium* was originally isolated by Snieszko and Friddle (1950) and shown to be the etiological agent of ulcer disease in trout.

One of the most serious diseases in young salmon is "kidney disease." During recent years there have been increasing numbers of outbreaks of this disease in chinook, sockeye and coho salmon (Earp, Ellis and Ordal, 1953). The disease is a generalized infection and is usually characterized by the presence of definite lesions of the internal organs, especially the kidneys. Large numbers of very small Gram-positive diplo-bacilli are always found in the lesions. On gross examination, the kidney is by far the organ most frequently affected, and because of the frequency with which characteristic

macroscopic lesions appear on this organ, the disease is commonly referred to as kidney disease. In advanced stages of the disease petechiae are frequently observed. In many cases, following damage to the kidney, there is an effusion into the peritoneal cavity. The fluid, often under pressure, contains large numbers of cells and the characteristic Gram-positive diplobacilli.

Kidney disease occurs over a wide range of water temperatures. Many outbreaks have begun during the autumn months during periods of declining water temperatures. Under these conditions the mortalities gradually but inevitably increase, exacting a serious toll from stocks of fish infected with the disease. When outbreaks of kidney disease occur during periods of moderate or warm water temperatures, the mortality rates may reach explosive proportions. Earp, Ellis and Ordal (1953) have presented epidemiological observations on outbreaks of kidney disease occurring in chinook, sockeye and coho salmon. In one outbreak of kidney disease in fall chinook salmon occurring at relatively high water temperatures, the weekly mortality rate rose from less than 1 percent to 26.6 percent in a period of eight weeks beginning in early July. The mean weekly water temperatures during this period ranged between 55° and 65° F. In an outbreak of kidney disease in spring chinook salmon the weekly mortality rose from just over 1 percent to 35 percent in a period of 11 weeks. During this period mean weekly water temperatures varied from 47° to 54° F. In an outbreak of kidney disease in a stock of sockeye salmon the mortality rose from around 1½ percent to over 24 percent in a period of four weeks, even though water temperatures were moderate, ranging from 47° to 51° F.

In our experience, the disease is more widespread in stocks of chinook and sockeye salmon, but recently instances of serious losses in coho salmon have occurred. Little opportunity is offered for the study of the possible occurrence of the disease in chum and pink salmon since these species remain in fresh water for only a short period before migration to the sea. It is known that the disease remains in infected stocks of chinook and coho salmon moved to artificial salt-water rearing ponds (Earp, Ellis and Ordal, 1953). Although most studies on kidney disease have been carried out in hatcheries, the disease has also been found in wild fingerling salmon. The disease is also known to affect species of trout as shown by Belding and Merrill (1935), Wales,⁵ and S. F. Snieszko.⁶

The etiological agent of kidney disease is fastidious in its growth requirements. It has been found to grow relatively rapidly on minced chick embryo tissues but slowly and with a prolonged lag phase on artificial culture media. In experimental infections introduced by injection and feeding of the agent, a long incubation period, usually from 15 days to in excess of 40 days is characteristic of the disease. Kidney disease has been produced in healthy stocks of young salmon both by feeding and by injection of pure cultures grown on minced chick embryo tissues and on artificial culture media, and the etiological agent has been reisolated from

⁵ Wales, J. H. Unpublished manuscript.

⁶ Personal communication.

experimentally infected fish. Koch's postulates have therefore been fulfilled.

The results of experiments on therapy have not been consistent. In field experiments on therapy, using sulfadiazine and aureomycin, mortality rates have been reduced but the disease has not been eliminated. In one laboratory experiment 40 sockeye salmon yearlings about 5 inches in length were injected with a pure culture of the etiological agent of kidney disease grown on chick embryo tissues. The fish were divided into two equal groups: one group was fed sulfadiazine at the rate of 12 grams per 100 pounds of fish for 10 days followed by 6 grams per 100 pounds of fish for an additional 10 days. The results of this experiment are presented graphically in Figure 1.

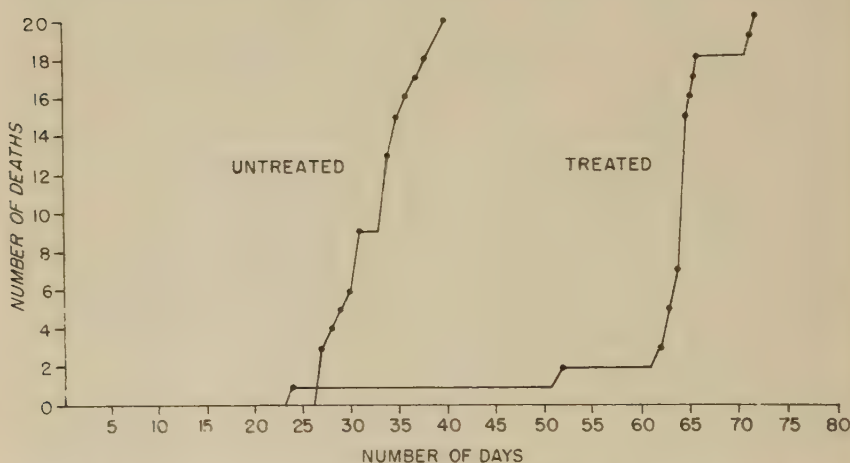


FIGURE 1.—Cumulative mortality curves of two groups of sockeye salmon inoculated with the etiological agent of kidney disease. The treated group received sulfadiazine in the food for the first 20 days. From Earp, Ellis and Ordal (1953).

The untreated fish died about 25 to 40 days after inoculation. The group fed sulfadiazine for 20 days had a delayed mortality period, and the majority of the fish died about 40 to 50 days after the sulfonamide was removed from the food. The most logical explanation is that some of the diplobacilli of kidney disease were still present and capable of developing after therapy was discontinued.

Some of the most important agents of disease in salmon are found among the myxobacteria. Many of the myxobacteria possess life cycles including a communal fructification stage closely analogous to that which occurs among the myxamoebae. Although most of the myxobacteria which have been described come from soil (Breed, Murray and Hitchens, 1948), we have found that they are commonly present in the aqueous habitats. The problem of studying the pathogenic species is therefore complicated by the presence in water of large numbers of saprophytic and parasitic forms which have not

yet been adequately described. Taxonomic studies on the myxobacteria occurring in fresh water are being carried out by E. J. Ordal. Myxobacteria from the marine environment are being studied at the University of Washington by T. J. Starr.

The first myxobacterium found to be pathogenic to fish was *Chondrococcus columnaris*. This organism was originally isolated in pure culture in the summer of 1942 by Ordal and Rucker (1944) during the course of an epizootic in sockeye salmon fingerlings at the U. S. Fish and Wildlife Service hatchery at Leavenworth, Washington. Experiments on transmission were carried out, and the disease, commonly referred to as "columnaris disease," was reproduced in salmonid fishes. Pure cultures of the etiological agent were reisolated from the experimentally infected fish, thus fulfilling Koch's postulates. A search for the primary source of the bacteria responsible for the epizootic in sockeye salmon led to the isolation of myxobacteria, identifiable as *Chondrococcus columnaris*, from the surface lesions and from the internal organs of adult chinook and sockeye salmon, steelhead trout (*Salmo gairdneri*), whitefish (*Prosopium* sp.), squawfish (*Ptychocheilus oregonensis*), chub (*Mylocheilus caurinus*), and suckers (*Catostomus* sp.) taken from the Columbia river. *C. columnaris* was also found in the organs of moribund adult sockeye and chinook salmon held in large outdoor ponds at the Leavenworth Hatchery. These fish had been trapped at Rock Island Dam on the Columbia River, and heavy mortalities had occurred during the period of holding. Once isolated the organisms were easily recognized as myxobacteria because of the shape and flexibility of the vegetative cells, the absence of a rigid cell wall and the characteristic myxobacterial motility in young cultures. The occurrence of spherical and oval microcysts, and of columnar or branching fruiting bodies which were not deliquescent, led to the assignment of the organism to the genus *Chondrococcus* following the key to the family Myxococcaceae of the order Myxobacteriales proposed by Stanier (1942).

The disease of the sockeye salmon fingerlings at the Leavenworth Hatchery was considered similar, if not identical, to a bacterial disease among warm-water fishes which had been described by Davis (1923). Fish and Rucker (1945) reported on the occurrence of this disease in cold-water fishes. Davis (1923) gave a comprehensive description of a new disease which he had observed in a variety of warm-water fishes, and noted that it was of consequence only during periods of high-water temperatures. Although he was unsuccessful in his attempts at cultivation of the bacterium observed in the lesions, he provided strong presumptive evidence of the causal relationship of these bacteria to the disease. An excellent description was given of the bacteria present in large numbers in the lesions. In particular Davis noted that when material from a lesion was placed on a slide in a drop of water, characteristic movements of the bacteria occurred, leading to the formation of short column-like masses. This column formation was considered characteristic of the species for which Davis proposed the name *Bacillus columnaris*. Apparently the organism was not considered to be a myxobacterium, since Davis (1923) in describing *B. columnaris* stated as

follows: "The bacteria are motile and probably possess flagella, although owing to the lack of facilities this has not been determined with certainty." However, to a bacteriologist, the myxobacterial nature of *B. columnaris* is suggested by the description of the vegetative cells occurring in lesions of infected fish.

The myxobacterium studied by Ordal and Rucker (1944) in its vegetative phase corresponded closely to *B. columnaris* in size, in shape, in flexibility and particularly in the characteristic movements, including the formation of column-like masses of cells. Studies with pure culture showed that the process of column formation represented an early phase in the production of aquatic fruiting bodies, in which microcysts were found after a period of maturation. Ordal and Rucker (1944) accepted the description of *B. columnaris* by Davis (1923) as a prior observation and in considering the taxonomy of the organism under study, retained the specific epithet "columnaris," but assigned the organism to the genus *Chondrococcus* as a result of the demonstration of its myxobacterial nature, and because of the production of oval or spherical microcysts in non-deliquestent fruiting bodies. It should be noted that the production of fruiting bodies in aqueous media, though a striking property, is not considered in determining the systematic position of a myxobacterial genus or species (see Breed, Murray and Hitchens, 1948).

The identity of *Chondrococcus columnaris* (Davis) Ordal and Rucker (1944) with *B. columnaris* (Davis 1923) has not been accepted by all investigators. Garnjobst (1945) isolated a myxobacterium from infected brown bullheads (*Ameiurus nebulosus*) at the U. S. Fish and Wildlife Service laboratory at Leetown, West Virginia, which she considered identical with *B. columnaris* (Davis 1923). This organism resembled *Chondrococcus columnaris* in its morphology and in its characteristic movements, but failed to produce microcysts and fruiting bodies and was designated as *Cytophaga columnaris*. No reference was made to the description of *Chondrococcus columnaris* by Ordal and Rucker (1944) and by Fish and Rucker (1945). Davis (1945) reported that *Cytophaga columnaris* was responsible for infections in brook trout (*Salvelinus fontinalis*) in the hatchery at Leetown, West Virginia, and that infections with this organism also resulted in serious mortalities among fingerlings and adult salmon at the U. S. Fish and Wildlife Service hatcheries at Leavenworth, Washington and Coleman, California. Davis (1947) reported that *Cytophaga columnaris* was responsible for outbreaks of disease in bullheads, salmon, and white crappies, and later Davis (1949), reported that *Cytophaga columnaris* was responsible for an epizootic resulting in the death of a large number of white crappies (*Pomoxis annularis*) in a reservoir near Pendleton, Oregon. In these reports no mention was made by Davis of the question of fruiting body production. On the other hand, Nigrelli (1943) reported that outbreaks of disease due to *Bacillus columnaris* occurred in several species of catfish at the New York aquarium. Subsequently, Nigrelli and Hutner (1945) reported on an epizootic in killifish (*Fundulus heteroclitus*) due to a similar organism. The myxobacteria present in the lesions were isolated in pure culture and

bacteriological studies carried out. Typical swarming and fruiting body production were observed in both fresh and cultured material, and the organism was diagnosed as *Chondrococcus columnaris*. Nigrelli and Hutner (1945) reported further that the organism isolated from killifish was morphologically and physiologically similar to a strain of *Chondrococcus columnaris* provided by Ordal and Rucker.

In view of the confusion in the nomenclature and taxonomic position of the etiological agent or agents of "columnaris disease," a few additional observations are presented. Ordal (1945) carried out further studies on the production of fruiting bodies by *Chondrococcus columnaris* using a variety of strains isolated from both rough and salmonid fishes. It was found that fruiting body production could be readily demonstrated by placing autoclaved fingerling salmonid fish in large flasks containing sterile tap water, and inoculating with the culture under study. Fruiting bodies, usually columnar, sometimes highly branched structures, appeared after a few days. The fruiting bodies extended a distance of 0.5 to 3 millimeters above the surface of the fish, and in some instances were packed closely together, covering almost the entire surface of the fish. It was concluded that the fruiting bodies occurring in dilute aqueous solutions could be considered as normal types. Sometimes atypical fruiting body production was observed, particularly with old laboratory cultures of *Chondrococcus columnaris*.

Borg⁷ carried out further studies on the production of fruiting bodies by *Chondrococcus columnaris* and found that freshly isolated strains characteristically produced fruiting bodies in which microcysts appeared after a period of maturation. The provision of a suitable dilute aqueous medium and the maintenance of aerobic conditions were found to be necessary conditions for the production and maturation of fruiting bodies. A series of strains of *Chondrococcus columnaris* carried in the laboratory for periods of up to three years were also examined. It was found that some of these strains produced colony types on solid media widely different from the original isolates. Some of these cultures failed to produce fruiting bodies, forming instead an envelope of slime in which bacterial cells were imbedded. With other strains definite fruiting bodies were observed, but maturation did not necessarily occur, and in these cases the microcysts were relatively few in number. Apparently the production of fruiting bodies is a complex process, and degenerative changes may occur in cultures of *Chondrococcus columnaris* when carried on artificial culture media leading to selection of strains which are incapable of production or maturation of fruiting bodies. This situation is not unique with *Chondrococcus columnaris*, since a number of investigators (Snieszko, McAllister and Hitchner, 1943; Woods⁸) have shown that a similar situation exists with species of fruiting myxobacteria isolated from soil. These findings indicate the desirability of testing for production of fruiting bodies in freshly isolated strains of aquatic myxobacteria.

⁷ Borg, Alfred Francis 1948. Studies on myxobacteria associated with diseases in salmonid fishes. 162 pp. Ph.D. thesis, University of Washington.

⁸ Woods, Nellie Angelina 1948. Studies on the Myxobacteria. 75 pp. M.S. thesis, University of Washington.

Borg⁷ considered the question of the taxonomy of the myxobacteria isolated from outbreaks of columnaris disease and agreed with Ordal and Rucker (1944) that the organism was properly named *Chondrococcus columnaris*. With respect to the organism isolated by Garnjobst (1945) it was suggested that non-fruiting strains of *Chondrococcus columnaris* might exist in nature and that *Cytophaga columnaris* might be an example of such a strain. Another possibility is that Garnjobst was dealing with a strain of *Chondrococcus columnaris* which had lost its capacity to produce fruiting bodies as a result of cultivation on laboratory media.

Davis (1946) as noted above, reported that infections with *Cytophaga columnaris* resulted in serious mortalities in fingerling and adult salmon at the U. S. Fish and Wildlife Service hatcheries at Leavenworth, Washington and Coleman, California. The outbreaks at Leavenworth, Washington were investigated by Ordal and Rucker (1944) and the etiological agent diagnosed as *Chondrococcus columnaris*. Cultures isolated at Leavenworth from sockeye salmon fingerlings in 1942 by Rucker⁹ were sent to Dr. H. S. Davis in 1942. Through the courtesy of D. W. Slater, cultures of myxobacteria isolated from outbreaks of columnaris disease at the Coleman Hatchery and elsewhere were made available. These cultures were studied by Ordal¹⁰ who found that some cultures produced typical fruiting bodies and were readily recognizable as *Chondrococcus columnaris*. Other cultures produced abortive fruiting bodies, such as often occur in old laboratory cultures of *Chondrococcus columnaris*. Unfortunately the culture of *Cytophaga columnaris* isolated by Garnjobst from bullheads at the Leetown Hatchery was not available to us for comparative study. However, Davis (1947) reported that additional outbreaks due to *Cytophaga columnaris* occurred at the Leetown Hatchery. Hence, should further outbreaks of columnaris disease occur at this station, it might be possible to resolve the discrepancy in nomenclature by studying freshly isolated strains of the etiological agent.

Chondrococcus columnaris is an important agent of disease, both in the hatchery and the natural habitat. In the summer, *Chondrococcus columnaris* can be found in impoundments behind dams, in lakes, streams and rivers. It is difficult if not impossible to determine the numbers of fish killed in naturally occurring epizootics because of predation, sedimentation and decomposition but evidence has accumulated that heavy mortalities can occur. For example, each summer for a number of years large numbers of dead and moribund rough and salmonid fishes have been found in shallow waters along the shores of Lake Washington. These fish show the presence of columnaris disease and *Chondrococcus columnaris* can be isolated from the majority of the specimens taken.¹¹

In our experience, the strains of *Chondrococcus columnaris* which have been isolated and tested at comparable water temperatures, fall into two categories with respect to virulence. The cultures isolated and tested for

⁹ Rucker, Robert Raymond 1944. A study of saprolegnia infections among fish. 92 pp. Ph.D. thesis, University of Washington.

¹⁰ Ordal, E. J. Unpublished data.

¹¹ Ordal, E. J. Unpublished data.

virulence, including strains obtained from rough fish and salmonids in Western Washington and from rough fish in the Columbia River, are characterized as low virulence strains. It is true that they can cause mass mortalities in hatcheries and in natural bodies of water when water temperatures reach rather high values. However, the infection is slow and insidious and tremendous tissue damage normally occurs before death ensues. The disease caused by these strains in hatcheries can be controlled to a degree by appropriate therapy with sulfonamides and pyridylmercuric acetate. Studies on therapy in fingerling salmon have been carried out by Slater (1948), Johnson and Brice (1953), R. F. Foster,¹² and Rucker.¹³

A number of strains of *Chondrococcus columnaris* which possess extremely high virulence have been isolated from both adult and young salmon in the Columbia River.¹⁴ When tested in the experimental hatchery, strains of this type cause fulminating infections in young salmon merely by contact or ingestion, with mortalities often reaching 100 percent in periods of 12 to 24 hours. The etiological agent can be recovered in almost every instance from the organs of the infected fish. Young salmonid fish infected with strains of *Chondrococcus columnaris* of high virulence seldom show large external lesions. Apparently death occurs before gross, external manifestations of the disease appear. It was found by Dyar and Ordal (1946) that a strain of *Chondrococcus columnaris* of high virulence for salmon possessed a lipid component in the cell membrane. This component was either absent or quantitatively less abundant in freshly isolated strains of low virulence. After cultivation on laboratory media for a period of 18 months, the culture was again tested. It was found that pathogenicity for salmon was lost, and the lipid component was no longer present. Although the property of high virulence is readily lost on subculture on laboratory media, it has not yet been possible to develop strains of high virulence from strains of low virulence by serial passage through salmonid fishes. Hence the natural source of these strains is still a mystery. There is a possibility that the strains of high virulence arise as a result of sexual recombinations in the complex life cycle of the organism. This question is under investigation.

Another well defined myxobacterium which is of considerable importance as an agent of disease in young salmon is *Cytophaga psychrophila*. This organism was isolated by Borg⁷ and found to be the etiological agent in epizootics in coho salmon occurring at relatively low mean water temperatures, i.e. 40° to 50° F. The disease was found present in six different hatcheries, and one group of approximately one million coho salmon fingerlings suffered a 31 percent loss. Borg noted that during the course of an epizootic some fish develop lesions just anterior to the tail, some fish showed lesions on the isthmus or over the back just anterior to the dorsal fin, while others become abnormally dark in color with no apparent surface lesions. *Cytophaga psychrophila* was isolated from the organs and lesions of the diseased fish. Three additional types of myxobacteria were isolated from

¹² Personal communication.

¹³ Rucker, R. R. Unpublished data.

¹⁴ Rucker, R. R. and E. J. Ordal. Unpublished data.

the lesions. These myxobacteria could be distinguished from each other and from *Cytophaga psychrophila* by morphology, biochemical reactions and by their ability to grow at temperatures of 75° F. or higher. *Cytophaga psychrophila* grew over the range 37° to 68° F. but failed to grow at 75° F. on the medium employed. The organism was diagnosed as a species of *Cytophaga* since neither fruiting bodies nor microcysts were formed by freshly isolated strains. The specific epithet "*psychrophila*" was applied to the organism because of the low maximum temperature of growth, and because of its role as an agent of disease at low water temperatures.

Further studies have been carried out by Earp and Ordal.¹⁵ It has been found that epizootics due to *Cytophaga psychrophila* occur every year in coho salmon in some hatcheries. In some outbreaks the fry are affected, in others the disease begins in the fingerling stage. The manifestations of the disease, as well as the course of a given epizootic, are profoundly influenced by prevailing water temperatures. The disease usually occurs in the spring when mean water temperatures are in the range of 40° to 50° F., and mortalities diminish with a rise in water temperatures. As a rule, the disease has run its course before the mean water temperatures reach 55° F. In a few outbreaks, mortalities have persisted to higher temperatures, *i.e.* around 60° F. The effect of temperature on the course of the disease has been investigated in the experimental hatchery. In one experiment a lot of approximately 2,000 fingerling coho salmon from a stock infected with *Cytophaga psychrophila* was brought to the experimental hatchery. These fish were held at a temperature ranging from 41° to 44° F. A heavy and persistent mortality occurred in these fish. Cultures were made at intervals and *Cytophaga psychrophila* was isolated from the majority of the dead or moribund fish sampled. A lot of approximately 180 fish was transferred to a separate trough and the water temperature raised to 55° F. The mortalities declined sharply after the first few days and after a week *Cytophaga psychrophila* could no longer be isolated. The disease persisted in the fish held at 41° to 44° F. and eventually all perished. The manifestations of the disease are also dependent upon water temperatures, and definite variation in virulence has been noted in strains of *Cytophaga psychrophila*. In one outbreak the daily mortality rate reached a level of 10 percent. At low mean water temperatures, *i.e.* in the range 40° to 45° F., relatively few gross external lesions are noted; however there is often a mantle anterior to the dorsal fin or near the peduncle. The fish characteristically darken in color before death. *Cytophaga psychrophila* can almost invariably be isolated in pure culture from the blood or organs of moribund fish, and usually from the mantle if it is present. At higher water temperatures ulcers or eroded areas are frequently found. Under these conditions cultures made from the blood or organs usually yield *Cytophaga psychrophila*, though occasionally other myxobacteria are also present. Cultures made from the eroded areas usually yield *Cytophaga psychrophila* and in addition several characteristically different types of myxobacteria. The latter are apparently secondary invaders.

¹⁵ Earp, B. J. and E. J. Ordal. Unpublished data.

The disease occurs mainly in coho salmon, though *Cytophaga psychrophila* has been isolated from organs and lesions during the course of an outbreak of disease in sockeye salmon. Chinook salmon appear to be relatively resistant. It has, however been noted that during the course of an epizootic in coho salmon, moderate rises in mortality rates may occur in parallel ponds of chinook salmon. In these instances *Cytophaga psychrophila* can often be isolated from the gills but not from the organs of the chinook salmon.

A number of other aquatic myxobacteria have been found to be pathogenic to salmon. In ordinary gill disease, myxobacteria are regularly isolated from the gills of affected fish. This type of gill disease is readily controlled with pyridylmercuric acetate or roccal and the myxobacteria are not recoverable from the organs of the fish. The specific characteristics of the myxobacteria isolated vary in different outbreaks. Apparently these myxobacteria are of limited pathogenicity.

Gill disease can take a more severe form, particularly in young chinook salmon. Here specific myxobacteria, as yet unnamed, can cause a generalized infection in addition to development on the gills. The etiological agent can be recovered from both the gills and organs of the fish and the disease does not respond readily to treatment with pyridylmercuric acetate or roccal.

A number of myxobacteria with definite invasive powers have been found in young salmon in conjunction with outbreaks of other types of disease. One interesting type produces ulcers in sockeye salmon at moderate temperatures when *Chondrococcus columnaris* is inactive.

DISEASES IN SEA WATER

A series of investigations, largely exploratory in character, have been carried out on the occurrence of disease in salmon in sea water (Earp and Ordal).¹⁶ Selected findings are presented in brief. The investigations on young salmon have been largely confined to fish reared in ponds supplied with pumped sea water. A number of diseases due to bacteria and other organisms have been found. One disease in young chinook salmon resembled columnaris disease but was due to a highly fastidious, halophilic myxobacterium. A disease in coho salmon, characterized by large muscular abscesses, was found to be due to a species of *Lactobacillus*. The disease was slow and chronic but eventually the entire population was lost. Another disease is due to a marine species of *Vibrio*. The disease is characterized by extensive hemorrhages throughout the musculature and the internal organs in which the vibrio is found in very large numbers. The disease first appears in the ponds in late April or May and continues through the summer during the period when the water temperatures approach 50° F. Bloody areas appear on the exterior surfaces of the fish and mortalities climb rapidly to high levels. All species of salmon are affected with catastrophic mortalities occurring in pink and chum salmon and lesser mortalities in chinook and coho salmon. Similar pathology has been found in Pacific herring (*Clupea*

¹⁶ Earp, B. J. and E. J. Ordal. Unpublished data.

pallasi) seined in Puget Sound. Various lots of these herring placed in live boxes died within 48 hours with hemorrhages in musculature and internal organs. The vibrio can be isolated from the lesions and blood of affected fish on simple peptone media provided sodium chloride is added in at least physiological concentrations. No growth is obtained on media without the addition of sodium chloride. Healthy fish injected with pure cultures of the vibrio usually die within 24 hours and exhibit the characteristic lesions. Therapy with sulfonamides, as employed for outbreaks of furunculosis, has been of value in controlling this disease.

Recently, an outbreak of disease with similar pathology occurred in rainbow and steelhead trout in fresh water at the Vancouver Hatchery of the Washington State Department of Game. This outbreak was investigated by Rucker and Ordal¹⁷ and the etiological agent was a halophilic vibrio resembling closely the organism responsible for the outbreak in salmon in sea water. The disease was noted following the feeding of salmon viscera and marine scrapfish. Heavy mortalities continued in legal-sized rainbow trout until sulfonamide therapy was given.

Tuberculosis has been found in adult chinook salmon taken during migration up the Columbia River.¹⁸ Since the disease was in an advanced stage of development it is likely that it was contracted at sea. Further evidence to this effect has come from the demonstration of tuberculosis in commercially caught chinook salmon taken near the mouth of the Columbia River.

It seems likely that disease due to micro-organisms may be of greater importance in the marine habitat than has hitherto been realized.

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¹⁷ Rucker, R. R. and E. J. Ordal. Unpublished data.

¹⁸ Earp, B. J., T. McKee, and E. J. Ordal. Unpublished data.

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THERAPY OF BACTERIAL FISH DISEASES

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ABSTRACT

During the past decade considerable progress has been made in the therapy of bacterial fish diseases. This progress was possible largely because of the introduction of powerful chemotherapeutic agents such as sulfonamides and antibiotics.

Fish furunculosis can be treated with very good results with sulfamerazine, sulfamethazine, and sulfaguanidine as well as by chloramphenicol and terramycin. Ulcer disease caused by *Hemophilus piscium* resists treatment with sulfonamides but responds well to the above mentioned antibiotics.

Chemotherapy of fish diseases caused by pseudomonads is possible with chloramphenicol, but sanitary measures are preferred. External disinfections with Roccal and pyridylmercuric acetate (PMA) are satisfactory in treatment and prophylaxis of gill diseases which are probably caused by superficial infections with myxobacteria. Sulfonamides are helpful in systemic infections with myxobacteria and are also being used with some success for the control of a recently described kidney disease of salmonoid fishes.

Also described are methods of control of other fish diseases and of immunity in cold-blooded animals and fishes. Most of the drugs in the described treatments may be toxic to fishes, and therefore should be used with caution.

INTRODUCTION

The therapy of bacterial diseases of fishes is essentially the same as that for higher vertebrates. However, in man and larger mammals, chemotherapeutic treatments are usually given to individuals and not to whole populations. Group treatment is applied normally to poultry because individual care, except especially valuable birds, would not be economical. The same is true with fishes. In the therapy of fish diseases, external disinfectants are used when the pathogenic bacteria produce superficial infections as in some forms of gill disease. Internal treatments with chemotherapeutic drugs, including antibiotics, are given for infections of the intestinal tract, internal organs, tissues, or in cases of septicaemias, such as in ulcer disease, furunculosis, myxobacterioses, and kidney disease.

Sulfonamides and antibiotics are the best known and most effective of the true chemotherapeutic drugs. Certain general principles should be observed in chemotherapy with sulfonamides (Northey, 1948) and antibiotics (Baron, 1950; Chandler, 1953). The experimental studies carried out in the laboratories provide information on which the final evaluation must be made through extensive and well controlled field trials. Most of the

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chemotherapeutic drugs should be given in sufficiently large doses and for long enough time to control the infection. On the other hand, a too prolonged treatment may be dangerous because of the possible toxic effect of the drug and the development of drug-resistant strains of pathogens. The author has been advised that in some cases of furunculosis, treatment with increased dosage of sulfonamides was not effective, and antibiotics have had to be used. Cultures of *Aeromonas salmonicida* isolated from such infected fish were highly resistant to sodium sulfamerazine *in vitro*. The indiscriminate use of drugs is very dangerous. Wholesale treatment of all diseases with a single drug is just as undesirable as "shot gun" therapy. Good sanitation should be stressed and given preference over therapy. Drugs should be used only when infectious agents penetrate the barricade of sanitation. In this review some well known fish diseases are discussed in relation to treatments of proven value introduced in recent years.

DISEASES CAUSED BY PSEUDOMONADS

Pseudomonads are common water bacteria. Some of them have been described as pathogens of cold-blooded vertebrates. Recently some species of these bacteria, which are active fermenters of various organic sources of carbon, were placed in the new genus *Aeromonas*. To this genus² belong two important fish pathogens: *Aeromonas liquefaciens* (formerly *Pseudomonas punctata*) which is the agent, or co-agent of infectious dropsy of carp and other fishes, and *Aeromonas* (formerly *Bacterium*) *salmonicida*, the etiological agent of fish furunculosis (Griffin, this symposium). Since both bacteria cause septicemia, the therapeutic and preventive measures that may be applied are chemotherapy, increase of immunity or resistance, and sanitary measures.

Fish furunculosis.—"No fish disease is to be feared more by the hatchery man than furunculosis, or the 'great red plague' of salmon and trout" (McCraw, 1952). Whenever outbreaks of this disease occur in trout hatcheries, most of the brook trout (*Salvelinus fontinalis*) are lost and mortalities among salmon, brown trout (*Salmo trutta*), and even some non-salmonoid fishes are heavy. Of the salmonoid fishes, rainbow trout (*Salmo gairdneri*) appear to be most resistant to this disease, but occasional epizootics with heavy losses have been reported. Since furunculosis was described 60 years ago, concerted efforts have been made to understand its nature and to develop methods of control (McCraw, 1952). Sanitary measures provided the only effective control of furunculosis prior to the introduction of sulfonamides and antibiotics. Infected fish were destroyed, the hatchery was disinfected, and trout cultures were started anew from uninfected or disinfected eggs (O'Donnell, 1947). Acriflavine (Smith, W. W., 1942, 1944) and sulfo-merthiolate (Gee and Sarles, 1942; Snieszko and Friddle, 1948) were found to be the best among the chemicals tested for disinfection of fish eggs.

² As recommended for the 7th edition of Bergey's Manual of Determinative Bacteriology, Williams and Wilkins, Baltimore, Md.

The treatment of fish populations infected with furunculosis became possible with the introduction of those sulfonamides which are also effective in the control of infections caused by gram-negative bacteria (Northey, 1948). Sulfonamides and other drugs were tried in the treatment of furunculosis by Gutsell (1946, 1948) who found that sulfamerazine was most effective; sulfathiazole and furacin also reduced mortalities considerably. Wolf (1947) confirmed Gutsell's results. Further studies (Snieszko, Gutsell, and Friddle, 1950) have shown that sulfamethazine, a drug closely related to sulfamerazine, although slower acting, is apparently equally effective in the treatment of brook trout populations infected with *A. salmonicida*. Treatment of furunculosis among brown trout with a mixture of sulfamerazine and sulfaguanidine gave satisfactory results (Flakas, 1950) and should be further investigated.

Experiments on dosage were carried out with infected fingerling and yearling brook trout (Gutsell and Snieszko, 1949a) who tested dosages of 44 to 260 milligrams of sulfamerazine per kilogram of fish per day (2 to 12 grams per 100 pounds). The optimum dosage was found to be 176 milligrams per kilogram of trout per day (8 grams per 100 pounds). With increased dosage (12 grams) the losses were slightly larger than at the 8-gram level, probably due to toxicity of the drug. The 4-gram rate though less effective than 12 grams reduced mortalities drastically. The 6-gram dosage gave nearly as good results as the 8-gram. However, the 8-gram dosage rate is recommended since it furnishes a margin of safety without losses attributable to the toxicity of the drug. The dosage of 8 grams per 100 pounds resulted in apparently complete cure of all the surviving yearling brook trout. *A. salmonicida* was recovered from the undersized fishes (runts) among fingerling brook trout which had been treated at the 6-gram daily rate. No undersized fishes and no carriers were found among the trout which survived in the controls. Since all small trout died in the controls, it seems possible that the runts in the treated lots received enough medicated food to arrest the disease but not enough to eliminate the pathogenic bacteria. Treatment of ungraded trout with sulfamerazine can be expected to suppress furunculosis, but not to eliminate it from the infected population. Therefore grading is necessary for effective chemotherapy of trout when the drugs are given with food.

In artificially infected 2-year-old brown trout, complete elimination of *A. salmonicida* was accomplished by a sulfamerazine-sulfaguanidine mixture, while sulfamerazine alone suppressed the symptoms of the disease without eliminating *A. salmonicida* from all fishes in a treated population (Flakas, 1950). On the basis of this observation and routine treatment of brown trout at one of the Wisconsin hatcheries, Flakas recommended a "multiple-sulfonamide" therapy. During the first 3 days, the trout should receive a mixture of 12 grams of sulfamerazine with 6 grams of sulfaguanidine for 100 pounds of fish per day. This treatment should be followed by a 7-day regimen of 6 grams of sulfamerazine and 4 grams of sulfaguanidine daily. It would be most interesting to repeat these experiments with brown trout and brook trout of various age groups since it is

known that tissue levels of sulfonamides vary in trout of different sizes (Snieszko and Friddle, 1951, 1952) and that the brown trout and brook trout react differently to sulfamerazine (Gutsell and Snieszko, 1949b).

In the evaluation of any new therapeutic agent, it is essential to determine: its effectiveness *in vitro* and *in vivo* against various microorganisms; the optimum therapeutic dosage; the toxicity to animals (or humans); and the effective concentrations of the drug in the blood, urine, or intestinal tract. When this information is available, the drug can be used intelligently and with a considerable degree of safety. The efficacy of sulfamerazine therapy of fish furunculosis was established before most of the properties of this drug towards the pathogen or the host were known. Treatments were undertaken in advance of careful study because any kind of promising therapy was urgently needed. However, to put sulfonamide therapy on a rational basis, it was necessary at least to determine the response of fishes to sulfonamides, the rate of absorption from the intestinal tract, retention in active form in the tissues, and elimination from the body.

A number of sulfonamides have been tested *in vitro*, for their bacteriostatic action against *A. salmonicida*. Sulfathiazole and sulfadiazine showed strong bacteriostasis; sulfamerazine was half as effective and sulfamethazine proved to be only weakly bacteriostatic (Smith and Nigrelli, 1947). In the trouts however, sulfamerazine and sulfamethazine produce higher tissue concentrations than do other sulfonamides (Snieszko and Friddle, 1951); this fact may explain their greater effectiveness in the therapy of furunculosis. In the testing of the effect of sulfamerazine on trout, Gutsell and Snieszko (1949b) found that the growth rate of fingerling rainbow trout was not affected by prolonged treatment at rates of 5, 10, and 15 grams of the drug per 100 pounds of fish per day. The growth rate of fingerling brook trout was reduced by higher dosages. The response of brown trout was most striking since all three dosage rates arrested the growth completely during the treatment (see also under "Toxicity"). Furunculosis appeared in the treated and control lots of brown trout. Apparently the good absorption of sulfamerazine by brown trout (Snieszko and Friddle, 1951, 1952) did not compensate for the reduced amount of the medicated food which the experimental brown trout took. The tissue concentration of the drug varies considerably among individual fishes even in a well graded trout population which has been treated for a number of days with food containing sulfamerazine. The tissue concentration also varies somewhat among fishes of uniform size given uniform doses of the drug in gelatin capsules. The relationship between the rate of feeding of the medicated food and the tissue concentration of sulfamerazine is very important. When the same amount of drug was mixed with variable quantities of food, the tissue levels of sulfamerazine were highest in those fish receiving the least food. This fact does not justify grossly underfeeding the treated fish, since that procedure would deprive of medication the weaker or smaller fish which are most difficult to treat (Gutsell and Snieszko, 1949a). In higher vertebrates and

humans, therapy is usually started with a high initial dose and then followed by lower maintenance doses. The experimental evidence seems to indicate however, that, in fish, a high initial dose has little effect on the tissue level of sulfamerazine during the subsequent period of maintenance dosage (Snieszko and Friddle, 1952). Flakas (1950) recommended a high initial dosage. Additional and very precise tests are required to determine the value of high initial dosages in the treatment of fish diseases with sulfonamides. Further experiments on the treatment of furunculosis and other fish diseases with combinations of sulfonamides or with sulfonamides and antibiotics also seem to be much needed.

The data on the tissue levels of sulfonamides in trout also explain the slower action of sulfamethazine in comparison with sulfamerazine. The two are equally effective in the treatment of fish furunculosis. Sulfamethazine however, is less bacteriostatic (Smith and Nigrelli, 1947) and is absorbed at a slower rate than sulfamerazine. The final tissue levels of the two drugs are equal (Snieszko and Friddle, 1951).

In addition to sulfonamides, terramycin and chloramphenicol are effective in the treatment of furunculosis (Snieszko, Griffin, and Friddle, 1952). At present sulfonamides are recommended for economic reason. Antibiotics are recommended for the treatment of furunculosis if ulcer disease also is present, or if the fish do not respond well (drug-resistant strain of *A. salmonicida*) to sulfonamide treatment (Anonymous, 1953).

Fish dropsy and other diseases.—The infectious fish dropsy seems to be important in warm-water fishes as is furunculosis in trout and salmon. Schäperclaus (1930) was the first to suggest that the most likely etiological agent of this disease is a common water bacterium, *Aeromonas liquefaciens* formerly *Pseudomonas punctata* (for synonyms see Griffin, this symposium).

Recently some German and Russian authors reported that in some cases, the primary cause of infectious fish dropsy is a virus. Nevertheless, *Aeromonas liquefaciens* and possibly other pseudomonads play a primary or at least important secondary role in a number of fish diseases (Griffin, this symposium). Recently, reports have been published in Canada (Reed and Toner, 1942), in this country (Seaman, 1951; Wagner and Perkins, 1952) and in Germany (Heuschmann, 1952) on diseases of trout caused by this pathogen. Obviously, the control of such diseases is important in practical fish culture.

Numerous German papers deal with the control of infectious dropsy by pond sanitation, quarantine, fish-management techniques, immunization, or even deliberate exposure to infection in order to eliminate the susceptible individuals from the population. Since the literature on this subject is voluminous, only certain of the more significant references will be given: Heuschmann, 1953; Schäperclaus and Mann, 1939; Schäperclaus, 1941; and Wunder, 1949.

The author knows of only four reports of successful chemotherapy of diseases attributed to *Aeromonas liquefaciens* (formerly *Pseudomonas hydrophila*). Most of the frogs which Smith (1950) treated for "red leg"

with a solution of chloramphenicol given by gastric intubation recovered and remained healthy during the observation period of several months. Ambrus, Ambrus, and Harrison (1951) prevented "red leg" by keeping frogs in water containing 50 milligrams of chloramphenicol per liter. Seaman (1951) obtained good results with sulfamerazine in rainbow trout suffering from infections with pseudomonads, as did Wagner and Perkins (1952), with a mixture of sulfathiazole and sulfamethazine and "some" antibiotics (details not reported). Terramycin at a concentration of 0.078 microgram per milliliter was found to be bactericidal to this organism *in vitro*. The reports quoted above indicate that the chemotherapy of fish diseases caused by pseudomonads is possible. It will be interesting to see how effective such therapy may be, and whether it can be applied to the treatment of fish dropsy in warm-water ponds.

ULCER DISEASE

Unquestionably there is more than one "ulcer disease" of fishes (Griffin, this symposium). Snieszko (1952) suggested that the term "ulcer disease" should be limited on the basis of priority and infection experiments to the disease of trout caused by *Hemophilus piscium*. The first but unsuccessful attempt at therapy of this disease was reported by Fish (1934) who recommended dips in copper sulfate in early stages of the infection. Tunison and McCay (1937) tried sulfanilamide and other chemicals, but without success. Wolf (1939) tested various disinfectants and diets, but obtained some success only with sulfamerazine (1947). Experiments at Leetown indicated that sulfamerazine therapy was ineffectual. It is possible that the outbreak which was controlled by sulfonamides (Wolf, 1947) was caused by a mixed infection of *A. salmonicida* and *H. piscium* or that other undetermined factors were involved. At Leetown and other hatcheries, several such mixed infections have occurred, the true etiology of which could be disclosed only by bacteriological examination. The test carried out *in vitro* with Difco "Sensitivity Discs" indicated that the zones of inhibition of growth were widest with chloramphenicol, somewhat narrower with terramycin, and even smaller with aureomycin. In the *in vivo* experiments carried out with fingerling and adult brook trout, chloramphenicol and terramycin administered orally at a rate of 50 milligrams per kilogram of fish per day were equally effective in the treatment of the ulcer disease and furunculosis. Aureomycin had no effect. Treatment with chloramphenicol gave fewer recurrences (Snieszko, Friddle, and Griffin 1951; Snieszko, Griffin, and Friddle 1952). It would be interesting to discover the reason for ineffectiveness of aureomycin *in vivo*.

INFECTIONS CAUSED BY MYXOBACTERIA

Myxobacterioses.—As far as we know now, fishes are the only animals which are subject to diseases caused by representatives of this group of bacteria which are common in soil and water. It is likely that more than one species of myxobacteria is pathogenic to fishes (Griffin; Rucker *et al.*,

this symposium). Fish usually succumb to "columnaris disease" (Davis, 1946), when the temperature of water rises to about 20° C. Psychrophilic forms pathogenic at lower temperatures also have been reported. Davis (1946) recommended treatment with 1:2000 copper sulfate; this solution apparently was satisfactory only in the early stages of the disease when the infection was still superficial. Fish and Rucker (1945) were not able to control myxobacterioses with any of the several surface disinfectants which they tested. The only surface disinfectant of promise is pyridyl-mercuric acetate.¹ Slater (1948) was the first to investigate the chemotherapeutic effects of various sulfonamides for the control of this disease in fingerling chinook salmon (*Oncorhynchus tshawytscha*). The best results were obtained with sulfamerazine and sulfadiazine; sulfamethazine was somewhat less efficacious. Sulfathiazole was without effect and food containing sulfanilamide was rejected by the fishes after several days of treatment. All sulfonamides tested were administered orally at a rate of 12 grams per 100 pounds of fish per day for a week, and the dosage was reduced by half during the second week. Sulfonamide therapy had only a temporary effect and the losses due to myxobacterioses increased shortly after treatment was discontinued. These results are in agreement with the observations of Snieszko and Friddle (1951) who reported that sulfamethazine was absorbed at a slower rate than sulfamerazine in fingerling brook trout, kept at the temperature of 12°–13° C., and that sulfathiazole could hardly be detected in the trout tissues. Sulfanilamide was toxic, probably because of its rapid absorption and the consequent high tissue levels. The action of sulfadiazine on myxobacterioses is most remarkable since in brook trout, it produced a tissue concentration only about half that reached with sulfamerazine. Johnson (1951) confirmed Slater's observations with rainbow trout treated with sulfamerazine. The therapy recommended by Slater was again tried on a large scale by Johnson and Brice (1952). Fingerling salmon of several species and trout which developed myxobacterioses at temperatures of 16° to 21° C. (60° to 70° F.) were treated with sulfamerazine and sulfadiazine as recommended by Slater. This therapy arrested mortalities among coho salmon (*Oncorhynchus kisutch*) and rainbow trout as long as it was continued. It had no effect on chinook salmon and the results were dubious with cutthroat trout. It is possible that the species of fish that did not respond to the treatment did not absorb enough sulfamerazine to develop a protective concentration in the tissues. Determination of the tissue levels of sulfonamides would be particularly desirable in these two species since it is difficult to believe that the drug resistance of the pathogen would change with the host. The results of Snieszko and Friddle (1952) have shown that sulfamerazine is easily absorbed by rainbow trout. This species also responds well to the sulfonamide therapy of myxobacterioses. Since none of the fish species studied by Johnson and Brice developed myxobacterioses at temperatures lower than 15° C. (60° F.), it seems logical

¹ Bryant, Maurice, Jr. The use of PMA in treating columnaris. Mimeographed report. October 1950.

that the most practical method for prevention of these diseases would be to rear fish at lower temperatures. When fish have to be reared in water at higher temperatures, the source of the infection (possibly carriers) should be eliminated from the water supply or the water should be freed from infectious agents. Perhaps automatic chlorination followed by dechlorination of the water supply would be practical when water-borne fish diseases are causing heavy losses. It would be unreasonable to expect that even an effective treatment with sulfonamides should produce durable results while the high temperature of water and the presence of pathogens make continuous reinfection possible. It is of interest that the Federal trout hatchery at LaCrosse, Wisconsin, which receives chlorinated city water which is dechlorinated before it reaches the fish (Sharp, 1951), is practically free from communicable trout diseases.

Gill diseases.—Gill disease or diseases are some of the most common maladies of young fishes. Due to the physiological role of gills in fishes, gill diseases can be compared to pneumonia combined with kidney damage in higher vertebrates. In warm-water fishes, gill infections of the hemorrhagic type are frequently caused by fungi belonging to the genera *Branchiomyces* (Schäperclaus, 1941). Other forms of gill diseases are caused by fungi belonging to the genus *Saprolegnia*, some by myxobacteria (*Chondrococcus columnaris* and others), and some probably by undescribed bacteria (see also Rucker *et al.*, this symposium). Evidence is also available that malnutrition may be a primary cause of gill disease (Wolf 1945, 1951a; Rucker, Johnson, and Kaydas, 1952). A hemorrhagic type of gill disease (Wolf, 1937), apparently different from that caused by a *Branchiomyces*, is frequent in the eastern United States. The above-mentioned diseases do not include infestations of the gills with various protozoan and animal parasites. Griffin, and Rucker *et al.* (this symposium) discussed the nature of gill diseases from a bacteriological point of view.

The fact that gill diseases of trout and salmon frequently respond favorably to treatments or prophylaxis with such disinfectants as roccal and pyridylmercuric acetate seems to support the theory that most of them either are caused by bacteria, or that in gill diseases of nutritional origin microorganisms may aggravate the symptoms greatly and play an important role as etiological coagents.

The early methods of treatment of gill disease were adequately reviewed by Davis (1946). Considerable progress in the therapy has been made during the past 10 years. One of the most important steps was replacement of dips in copper sulfate by prolonged-treatment methods. Copper sulfate is apparently still useful in the control of some gill diseases among farm-water pond fishes (Heuschman, 1953). Fish (1947) reported effective control of gill disease by prolonged treatment with roccal (the trade name for a 10-percent solution of high-molecular alkyl-dimethyl-benzyl-ammonium-chlorides). He recommended that the roccal be evenly distributed in water at a concentration of 1:50,000 and the fish treated for 1 hour. Since the composition of roccal is not constant the bactericidal and toxic properties may vary in different batches (Rucker, 1948; Rucker, Johnson,

and Ordal, 1949). In hard water calcium and magnesium bicarbonates greatly reduce the bactericidal efficiency of quarternary ammonium compounds (Chambers, Weber, and Bryant, 1953). The chelating agents counteract somewhat this effect of hard water (MacGregor and Elliker, 1953).

Pyridylmercuric acetate (PMA) is another compound of value in the treatment of gill diseases in salmon and trout, and of external protozoan infestations in all fishes. It is used in its technical form (Van Horn and Katz, 1946). Rucker (1948) found that a single 1-hour application of PMA diluted to 2 p.p.m. will remove the bacteria from the surface of the gills and lead to a complete recovery of the infected salmon. Snieszko (1949) confirmed Rucker's observations and Burrows and Palmer (1949) reported that PMA used at a rate of 2 p.p.m. not only gave excellent results in treatment of gill diseases, but also of infestations with *Costia* and an unnamed stalked ciliate. PMA has a wide margin of safety; fingerling sockeye salmon (*Oncorhynchus nerka*) survived 90 minutes in concentration of 1:45,000; the lethal concentration was 1:30,000. Burrows and Palmer did not give information on the sizes of the experimental fish, or the range of water temperature. They determined also that PMA was not toxic to salmon fingerlings of two other species or to fingerling brook trout and rainbow trout.

Wide-scale use of PMA soon disclosed some limitations to its application. Prompted by Seaman's (1950) report of mortalities among trout treated with PMA, Rodgers *et al.*, (1951) conducted tests that showed this compound to be toxic to larger fingerlings and older rainbow trout. Prophylactic treatments can be made at biweekly periods rather than weekly and the concentration can be reduced to 1 p.p.m. in the treatment of fingerling sockeye salmon if the ratio between fish and the water in which they are reared is no less than 1:70 by weight (Burrows, 1951). The effect of temperature on the required frequency of treatments was not investigated.

An entirely new approach to the treatment of gill diseases has been made during the past decade. Since it is likely that very few of the chemicals, disinfectants or drugs with potential value were tested to date, we can anticipate new discoveries in the therapy and prophylaxis of gill diseases. The nutritional approach to the control of these diseases is also important.

FIN ROT

Little progress has been made in explaining the etiology of fin rot. Although in some cases undetermined bacteria were seen in the affected tissues and even isolated, no one has established their role in this disease (Davis, 1946). From trout with symptoms of fin rot, *H. piscium* and *A. salmonicida* were isolated along with other undetermined species in this laboratory. The early methods of treatment were limited to dips in copper sulfate (Wright, 1936) or treatment with potassium permanganate. Burrows (1941) reported satisfactory results with a prolonged treatment with

formalin (1:4000). No attempt was made by the latter author to establish the cause of the disease, but since formalin produced good results one could suspect that protozoans may have played some role in the epizootic described by him. Chlorine treatment, even if promising, is so exacting that it must be carried out with great skill if it is not to be dangerous to the treated fish (Connell, 1937). Hewitt (1937) obtained good control of this disease by periodic disinfection of the troughs with chlorine (of course, the fish were removed during decontamination). A treatment with formalin (1:2,000 for 1 hour) followed by a flush treatment with malachite green was effective according to Eicher (1947). Phemerol, one of the quaternary ammonium disinfectants, was tested by McLaren, *et al.*, (1947). The best results were obtained by dipping the infected trout in an aqueous solution of crystalline Phemerol (1:10,000) for 30 seconds; Prolonged treatments were not tested. According to Wolf (1938), underfeeding predisposes the trout to fin rot; nipping by other fishes may also be of significance. Doudoroff (1938) found that keeping fish in black containers may increase susceptibility to fin rot. Excessive illumination or ultraviolet radiation also may cause fin rot and other pathological changes (Lassleben, 1952). Improvement was noticed when these predisposing conditions were removed.

KIDNEY DISEASE

Kidney disease is common among salmon and trout on the West Coast (Earp, Ellis, and Ordal, 1953), and serious outbreaks occurred also in some of the trout hatcheries in New England and New York State.² The disease is caused by a microorganism which grows much better in the animal tissues than in bacteriological media. In observations made at the Leetown station the pathogen was seen in large numbers both extra- and intracellular. It may be surmised from these facts that some relationship may exist between the kidney-disease organism and the *Rickettsiales*. It is not surprising, therefore, that, despite temporary arrest by sulfonamides of its multiplication in the tissues of fish infected by parenteral injection, the fish became sick and died when the therapy was discontinued. If, however, the disease was transmitted naturally through water, treatment with this sulfonamide resulted in satisfactory although not complete prophylaxis (Rucker, *et al.*, 1951). It is of interest that in lymphogranuloma venereum infections in humans, certain sulfonamides are able to hold the infection in check, but the virus within the cells is not killed (Bedson *et al.*, 1950).

IMMUNIZATION

The effective and widespread use of chemotherapeutic drugs for the treatment of infectious diseases is of recent origin. In the past the main weapons were sanitation, immunization, and serotherapy. Although many volumes were published on immunity and immunization in diseases of humans and higher vertebrates, little work was done with fishes.

² L. E. Wolf, personal communication.

The production of antibodies in fishes, which are poikilothermous animals, is affected by the temperature of the water. To mention just the more recent studies, Nybelin (1935) found that eels did not produce agglutinins at a temperature of about 8° C. but immune sera of high titer were produced at about 18° C. These results were confirmed by Snieszko *et al.* (1938) with carp immunized against the infectious dropsy. Similar studies on carp and trout were reported by Smith (1940). Further detailed data on immunity of carp against this disease (Mann, 1939) indicated that the production of antibodies varied considerably according to the season of the year. This fact may explain the seasonal fluctuations in the outbreaks and the severity of this infection. Some very interesting observations on the relationship between resistance to infection and disease, and the temperature in the poikilothermous animals were reported by Bisset (1946, 1947). He wrote in the first paper "... that fish may become parasitised, sometimes heavily, by saprophytic water bacteria. Normally this causes little pathological effect, but under exceptional circumstances disease and even death may result. There appears to exist, at low temperatures, a balance between the aggressive action of the bacterium and the defensive powers of the host. Under such conditions the infected fish might be likened to a healthy carrier of a specific pathogenic organism. When the temperature is raised the balance is upset, probably by changes in the metabolic activity of both host and parasite. In these circumstances, if the fish is previously uninfected its defenses will be so greatly increased that it becomes completely resistant to infection. If, on the other hand, bacterial parasitism has already become established, the bacteria tend at first to increase and a proportion of the fish may die. In time, however, the surviving fish succeed, in many cases, in eliminating the bacteria from their bodies." This may explain many heavy mortalities among fishes in warm-water ponds during spring. Many of these infections are believed to be caused by pseudomonads, chiefly *Aeromonas liquefaciens* (*Pseudomonas punctata*). Since infections caused by pseudomonads usually respond well to antibiotics like chloramphenicol, terramycin and aureomycin, one could try treating infections in valuable brood stock fishes with antibiotics during the period of raising temperature of water in the spring, until the temperature becomes high enough for the production of specific antibodies.

Oral administration of antigen (Thomson *et al.*, 1948) offers a simple but not highly effective method of immunization. Although Duff (1942) found oral immunization of cutthroat trout against natural infection promising, the protective value is doubtful particularly against intramuscular injection (Snieszko and Friddle, 1949). The problem may be worth reinvestigation since Duff (1937) indicated that *A. salmonicida* dissociates into various colonial types in phenol and lithium chloride broth. Duff found an opaque, convex, cream-colored variant which he termed a rough (R) type which was stable on prolonged subculture. What is more important, this variant was also non-pathogenic! The present author feels that such a variant offers an exceptionally fine approach to the immunization of trout by living, attenuated cultures. The possibility of establishing

a stable, living, non-pathogenic variant of *A. salmonicida* in a given fish population appears promising, since the carrier state is known in furunculosis, and little or no leukocytic response is obtained in this disease. The problem merits investigation. Duff's work also is indicative of the relative ease with which *A. salmonicida* can mutate.

TOXICITY OF DRUGS USED IN THE TREATMENT OF BACTERIAL FISH DISEASES

The ideal chemotherapeutic drug should be invariably toxic to the pathogenic microorganism but entirely harmless to the host. Since such drugs are not yet known, one has to be satisfied with substances that have the widest possible margin of safety between the effective dosages and their toxic levels. This discussion will mention only those materials that are used with satisfactory results in the treatment and prevention of bacterial fish diseases.

Sulfonamides and antibiotics are the best antibacterial drugs. Toxicity of the former to fishes was first investigated by Litchfield (1939). Parenterally introduced sulfanilamide was found to be toxic to Atlantic spiny dogfish (*Squalus acanthias*) when the blood level of this drug was above 5 milligrams per 100 milliliters, but acute symptoms and death occurred at the blood levels of 10 to 12 milligrams. In tests with various animals, sulfanilamide was about 15 times more toxic to fish than to frogs and about 4 times as toxic as to chickens. Attempts to produce anemia in fish were unsuccessful even after 7 days of treatment. Gutsell and Snieszko (1949b) determined the effect of sulfamerazine on fingerling trout of three species treated at the water temperature of 12° to 13° C. The growth of rainbow trout was not affected even after 40 days of continuous treatment. The growth rate of brook trout was reduced in proportion to the dosage, but no gross toxic effects were noticed. The growth of brown trout was completely arrested during treatment by dosage rates of 5 to 15 grams per 100 pounds of fish per day. Brown trout suffered no mortalities that could be attributed to the toxic effect of the drug, and the hemoglobin content was significantly higher (analysis of variance) in the treated fish. In brown trout and brook trout treated continuously at a constant dosage rate, the concentration of sulfamerazine increased in the tissues for about 10 days and afterwards started to decline, whereas in the rainbow trout, the tissue level of the drug rose slowly but steadily during the 3 weeks of treatment (Snieszko and Friddle, 1951, 1952). Johnson and Brice (1953) observed that sulfamerazine was toxic to fingerling silver salmon 1 to 3 grams in weight treated at about the same temperature (10° to 12° C). Somewhat larger salmon (more than 6 grams) kept in warmer water were not affected. It is not known whether the age of fish, the temperature of the water, or both, brought about this difference. Litchfield (1939) found that sulfanilamide was more toxic to frogs at 5° than at 15° C. Additional observations on the effect of sulfanilamide on fish (Snieszko and Friddle, 1951) have shown that while the uptake of this

drug through the intestinal tract was good, the tissue level dropped much faster, despite continuous treatment, than that of any other sulfonamides tested.

Observations not yet tested experimentally, give cause to suspect that prolonged treatment with sulfonamides may impair reproduction in trout. Acriflavine (Pickford, 1952), a disinfectant used in the treatment of aquarium fishes and in the disinfection of trout eggs, slowed the growth of *Fundulus heteroclitus* and retarded development of the testes. The latter effect could be prevented by the addition of *Daphnia* to the diet.

The new external disinfectants used in the treatment of gill disease and external parasitic infestations are also toxic to fishes. Rucker, Johnson, and Ordal (1949) found that the mixture of alkyl-dimethyl-benzyl-ammonium chlorides (sold under the trade name "Roccal") in which the homologues contained 10, 12, and 14 carbon atoms in the alkyl chain had the strongest bactericidal properties toward *Chondrococcus columnaris* and the least toxicity to fish. Homologues containing 16 and 18 carbon atoms were more toxic to fish than to the bacteria. They determined also that the substitution of the benzyl radical for a methyl group on the central nitrogen atom profoundly influenced the relative toxicity to fish and bacteria.

Pyridylmercuric acetate (PMA, technical) which is now widely used for the treatment of gill diseases and external parasitic infections, has been found to be non-toxic at various water temperatures up to the age of 1 year in the sockeye, chinook and coho salmon, as well as brook trout and rainbow trout (Burrows and Palmer, 1949). This chemical is toxic, however, to rainbow trout (Rodgers *et al.*, 1951). In experiments conducted by these authors brook trout and brown trout were not affected, and in rainbow trout less than 3 inches long, the toxic effect was limited to loss of appetite for about 1 day following the treatment. According to Foster and Olson (1951), however, it was frequently fatal to rainbow trout particularly at higher temperatures. Wolf (1951b) confirmed these results and found that PMA was also non-toxic to Atlantic salmon and lake trout. Rucker and Whipple (1951) also have found PMA toxic to 3-inch rainbow trout. Malachite green was found by the same authors to be slightly toxic to small rainbow trout and lethal to 3-inch sockeye salmon. The explanation of the nature of the specific toxicity of PMA to larger rainbow trout would be most interesting.

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VIRUS DISEASES OF FISH

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ABSTRACT

Viruses are probably the cause of a wide spectrum of fish diseases. Although relatively few virus diseases of fish are known today, some of the diseases of unknown etiology, as well as some diseases presently accepted as due to bacteria, protozoa, fungi or nutritional deficiencies, possibly will be recognized eventually as virus diseases.

Some viruses may induce proliferative tissue changes whereas others may cause degenerative change. Although several diseases of a proliferative nature have been reported to be of virus origin, positive experimental evidence for the transmission of a virus from one fish to another, has been presented for only lymphocystis.

The degenerative or non-neoplastic diseases of possible virus origin give the fish-culturist the most concern because of the severe mortalities resulting from infection. Epizootics of this nature have been reported in carp (*Cyprinus carpio*) and rainbow trout (*Salmo gairdneri*) in Europe, in acara (*Geophagus brasiliensis*) in South America, in kokanee, (*Oncorhynchus nerka kennerlyi*) and in sockeye salmon (*Oncorhynchus nerka nerka*) in the State of Washington. It has been demonstrated that each epizootic was caused by an infectious filterable agent, probably a virus.

INTRODUCTION

Contagious diseases of fish have created problems since the first attempt by man to rear fish in hatcheries. With the development of microbiology, contagious diseases of fish have been attributed to protozoa, fungi, bacteria and larger organisms (e.g., trematodes). Other diseases, such as fish pox (Roegner-Aust and Schleich, 1951), are well known, but the nature of the etiological agents has remained in question. Recently some of these diseases have been shown to be caused by viruses.

Unfortunately, viruses do not lend themselves to direct investigation as easily as do most of the larger microorganisms. Unlike most bacteria, they cannot be grown *in vitro* except in tissue cultures, since they are obligate intracellular parasites. Likewise, viruses cannot be seen with the ordinary light microscope because of their small size. Thus, positive proof that a disease is of virus origin is difficult to obtain. To establish a virus as an etiological agent some of the following arbitrary criteria have been used in such textbooks on virus as that of Rivers (1948):

1. The primary requisites are that the etiological agent passes through bacteria-tight filters, that the agent is infectious, and that the agent is transmissible in series in the experimental animal.
2. The absence of microorganisms other than viruses in exudates and diseased tissues constitutes evidence, but not proof, that a disease may be caused by a virus.

There may be present either secondary invaders or such microorganisms, spirochaetes and rickettsia, which are difficult to demonstrate with ordinary techniques.

3. The presence of inclusion bodies in some diseases (as Negri bodies in rabies) offers a highly reliable indication of a virus infection. Recognition of virus inclusions requires experience, since various intracellular structures (e.g., fluid vacuoles, glycogen droplets, and large eosinophilic nuclei) may be mistaken for inclusion bodies (Pinkerton, 1952). There are, however, many virus diseases in which no inclusion bodies have been demonstrated.

4. Examination under an electron microscope is useful for the demonstration of virus particles in diseased tissues or exudates, but it should not be used as a sole basis for diagnosis since protein and other molecules may be confused with virus particles.

5. An infectious agent causing neoplasia or hyperplasia is likely to be a virus. Pinkerton (1952) stated that, "Other than intact tumor cells, the only transmissible agents which are known to cause neoplasia are certain filterable agents, generally accepted as viruses, which induce tumors in lower animals and plants."

This paper is intended as a review and evaluation of the literature on virus diseases of fish. The review was prompted by an uncontrollable virus disease in sockeye salmon being raised in hatcheries in the State of Washington (Rucker, *et al.*, 1953). Some work which is being done by the writer on a virus disease of sockeye salmon will also be reported.

NEOPLASTIC AND HYPERPLASTIC DISEASES

Fish diseases characterized by proliferative tissue changes are numerous, but evidence that they are caused by viruses is largely circumstantial. Only a brief discussion of neoplastic and hyperplastic diseases will be given since Nigrelli (1952) recently reviewed the subject.

Fish Pox.—Fish pox is one of the earliest diseases of fish reported in which proliferative changes are involved. This disease, (according to Roegner-Aust, 1953) was described as early as 1563 by the naturalist Gessner and is still prevalent in Europe, (Roegner-Aust and Schleich, 1951). Although the disease does not cause severe mortalities, rather large economic losses are suffered because afflicted fish are not marketable.

Fish pox produces whitish opaque spots on a thickened epidermis of carp and related cyprinids. The hyperplasia of the epidermis is microscopically indistinguishable from a true neoplasm; however, it may spontaneously regress and disappear (Schlumberger and Lucké, 1948).

Epizootiological evidence indicates that fish pox is an infectious disease, although transmission experiments have not been successful. The presence of inclusion bodies in infected cells, demonstrated by Loewenthal (according to Nigrelli, 1952), Plehn (1910) and others, indicated the possibility that a virus was the infectious agent. Roegner-Aust and Schleich (1951) have recently studied these inclusion bodies with an electron microscope and found that they contain granules which were interpreted as elementary bodies. Thus, subject to additional investigation this disease is tentatively designated as one of virus origin.

Lymphocystis.—Lymphocystis is a disease in which the infected cells undergo hypertrophy. Evidence indicates that this disease is of virus origin. Lymphocystis was described originally in a European flounder (*Pleuronectes flesus* and *P. platessa*) in 1874 by Lowe (according to Nigrelli and Smith,

1939). It was first reported in the United States in the walleye, by Mavor and Feinberg (1918). More recently it has been found in a wide variety of both fresh- and salt-water fish including the walleye (*Stizostedion vitreum vitreum*), the blue angelfish (*Angelichthys isabelita*), the hogfish (*Lachnolaimus maximus*), the orange filefish (*Aleutera* [*Ceratacanthus*] *schoepfi*), the killifish (*Fundulus heteroclitus*), and others (Smith and Nigrelli, 1937; Weissenberg, Nigrelli, and Smith, 1937; Weissenberg, 1938 and 1939). The disease is chronic, lasting 1 to 3 years. High mortalities have not been reported, but in Saginaw Bay infected walleyes have been found to weigh $5\frac{1}{2}$ to $6\frac{1}{2}$ percent less than sound fish of the same length.¹

Lymphocystis is characterized by the development of small, irregular, solitary or confluent nodules, often distributed laterally on the body or on the fins. Microscopic examination reveals a gigantic hypertrophy of osteoblasts and fibroblasts as well as a peculiar transformation of infected cells. The so-called "lymphocystis cell" reaches a diameter of 5 millimeters or more and is surrounded by a thick, transparent membrane. Conspicuous structures which have been interpreted as inclusion bodies have been seen in these infected cells by Weissenberg, Nigrelli, and Smith (1937), Nigrelli and Smith (1939), Weissenberg (1949 and 1951a), and others.

Specific granules in the outer layers of the inclusion bodies have also been demonstrated and interpreted as elementary bodies (Weissenberg, 1949 and 1951a; Alexandrowicz, 1951). Weissenberg (1951a) and others have followed the development of these inclusion bodies and granules; the evidence indicates that they are of possible virus origin. More conclusive evidence suggesting a virus as the etiological agent was found when Weissenberg (1951b) transmitted the disease experimentally to healthy fish with bacteria-free filtered material from an infected fish.

Other diseases of a neoplastic nature considered to be infectious, and therefore, probably of a virus origin, are fish papillomas and certain lymphosarcomas (Nigrelli, 1952).

NON-NEOPLASTIC DISEASES

There are undoubtedly many virus diseases of fish in which the primary effect is destruction and necrosis of the host cells. Such diseases include the European infectious dropsy of carp, the South American disease of acara, the European kidney disease of rainbow trout, and the disease of sockeye salmon in the State of Washington.

Infectious dropsy of carp.—Infectious dropsy has been known for a number of years in carp. Pestilent outbreaks of the disease with resultant severe mortalities and economic losses have occurred in Europe since the eighteenth century (Layman, 1949). Severe epizootics occurred in Germany in 1928 and spread to Holland, Scandinavia, Czechoslovakia, and Poland. In 1936 and 1937 the number of epizootics of infectious dropsy decreased gradually. Epizootics in Russia declined from 1938 to 1941, but the disease again resumed epizootic proportions in 1942 and 1943.

¹ Dr. Ralph Hile, private communication, 1953.

Some fish-culturists were forced to abandon the culture of carp for a time and to rear other kinds of fish to avoid mortality rates of 60 percent or more (Layman, 1949).

Originally, Schäperclaus thought that *Pseudomonas punctata*, the etiological agent in infectious dropsy (Nigrelli, 1952), but in 1937 Schäperclaus (according to Roegner-Aust, 1953) suggested the possibility of a virus as the primary agent. Bacteria-free filtrates of coelomic fluid of diseased carp were infectious, whereas bacteria-free filtrates of coelomic fluid from fish inoculated experimentally with *P. punctata* were not infectious. Schäperclaus (1953), now seems to discount the possibility of a virus as the etiological agent, since he was able to demonstrate that exotoxins from *P. punctata*, inoculated into carp would cause the symptoms of dropsy. Dombrowski (1953) recently reviewed the question "Bacterium oder Virus?" He expressed the firm belief that *P. punctata* rather than a virus was the etiological agent in infectious dropsy.

Other workers, however, have presented fairly convincing evidence that a virus, if not the primary etiological agent, at least contributes to the symptoms of infectious dropsy. This work has included filtration and agglutination experiments, cytological studies, and differential blood counts by Layman (1949) and electron-microscope studies by Roegner-Aust, Brunner and Jaxtheimer (1950), Roegner-Aust, and Schleich (1951), and Roegner-Aust (1953).

From my review of the literature I believe that additional work, including serial transfers of bacteria-free suspensions of infected material as an inoculum, is needed before the etiological agent of infectious dropsy can be established with certainty.

European kidney disease.—Schäperclaus (1941) described an infectious kidney disease among rainbow trout in European hatcheries that may be of virus origin. The disease was reported to cause 30- to 60-percent mortality in rainbow stocks. During the course of the disease, the only noticeable external symptom was the dark color of some fish. Autopsy revealed that the kidney was swollen, corrugated, brown, and mottled with white. Schäperclaus was not able to demonstrate the presence of bacteria in diseased tissue, but he showed that healthy fish which were inoculated with a bacteria-free filtrate of diseased tissue developed the original symptoms of the disease.

Similar, if not identical, kidney diseases have been described by Belding and Merrill (1935) in brook trout (*Salvelinus fontinalis*) and rainbow trout at hatcheries in Massachusetts, by Wales² in brook, rainbow and brown trout (*Salmo trutta*) at hatcheries in California, and by Earp, Ellis, and Ordal (1953), in chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*) and sockeye salmon at hatcheries in the State of Washington. Earp was able to demonstrate a gram-positive diplo-bacillus as the causative agent and was able to obtain growth of this microorganism on a non-living culture medium after prolonged incubation. Earp could not demonstrate that the infectious agent was filterable. Because of the patho-

2 J. H. Wales, private communication.

logical similarity among all of the described kidney diseases, additional investigations are needed to determine whether the same etiological agent is involved.

South American virus disease.—Description of a virus infection called “cryo-ichthyozoose” has been reported in economically important river fish in the state of Sao Paulo, Brazil, by Pacheco and Guimaraes (1933) and Magarinos and Pacheco (1934). Healthy fish contracted the disease when exposed to contaminated water which had been passed through a bacteria-tight filter. The infective powers of this virus disappeared at temperatures greater than 16° C. Macroscopic examination of diseased fish revealed circulatory congestion at the base of the fins, some posture modifications, pale gills and viscera, and mucus in the mouth and stomach. The gall bladder appeared as a dark-red, membranous sac containing a sticky, amber-colored bile.

Magarinos and Pacheco (1934) experimentally infected acara with this virus. Microscopic examination of the buccal-cavity epithelium showed stomatitis complicated by eosinophilic cytoplasmic inclusions and swollen nuclei. There was no evidence of hyperplasia or general increase in cell size.

Diseases of sockeye salmon.—Severe mortalities have occurred in hatchery-reared sockeye salmon fry and fingerlings in the State of Washington for the past several years (Rucker *et al.*, 1953). Several micro-organisms, including *Pseudomonas hydrophila* and the gram-positive diplobacillus of kidney disease (Earp, Ellis and Ordal, 1953) have been suspected as the etiological agents in some of the epizootics. No conclusive evidence implicating any particular microorganism was found prior to 1951.

An epizootic of possible virus origin occurred in 1951 in the federal hatchery at Leavenworth, Washington. This disease affected fingerlings of both the sockeye salmon and kokanee, but did not affect fingerlings of the chinook salmon, coho salmon, or cutthroat trout (*Salmo clarki clarki*).

This epizootic was characterized by its explosive nature, by severe mortalities, and by the failure of therapeutic measures to control or alleviate the disease. A small percentage of the afflicted fish developed retracted heads and spinal deformities resembling scoliosis and lordosis.

When the disease in sockeye salmon was recognized in 1951, it was confined to 6 of 102 hatchery troughs. The epizootic started about March 20, 1951, and a 33.5 percent mortality had occurred in the 6 troughs by April 19. By the third week of May, nearly all the fish were dead in the infected troughs.

The epizootic among the kokanees at the Leavenworth station occurred in late June and early July of 1951. This disease was more general in the hatchery, but all troughs were not infected. The cumulative mortality attributed to this disease reached 39.6 percent of all hatchery stock by October.

A similar epizootic occurred in sockeye salmon fingerlings at the same hatchery in June 1952. All 11 ponds, each stocked with approximately 200,000 sockeye salmon, became infected during June.

Mortality in sockeye salmon ponds is usually about 0.01 percent per day

under normal conditions, but rose to 1 percent per day in 6 to 9 days after infection. The daily mortalities in individual ponds then rose to a maximum of 28 to 32 percent a day during the next 12 to 16 days. In 16 to 26 days after the onset of infection the cumulative mortality had risen to 50 percent. In another 11 days 90 percent of the fish were dead. The mortality then decreased gradually to 0.02 percent per day. In the latter part of September the mortalities rose slightly from 0.07 to 0.9 percent per day, and remained nearly constant until the latter part of October. By late September approximately 145,000 survivors remained from the original population of 2,872,000 fish (Fig. 1).

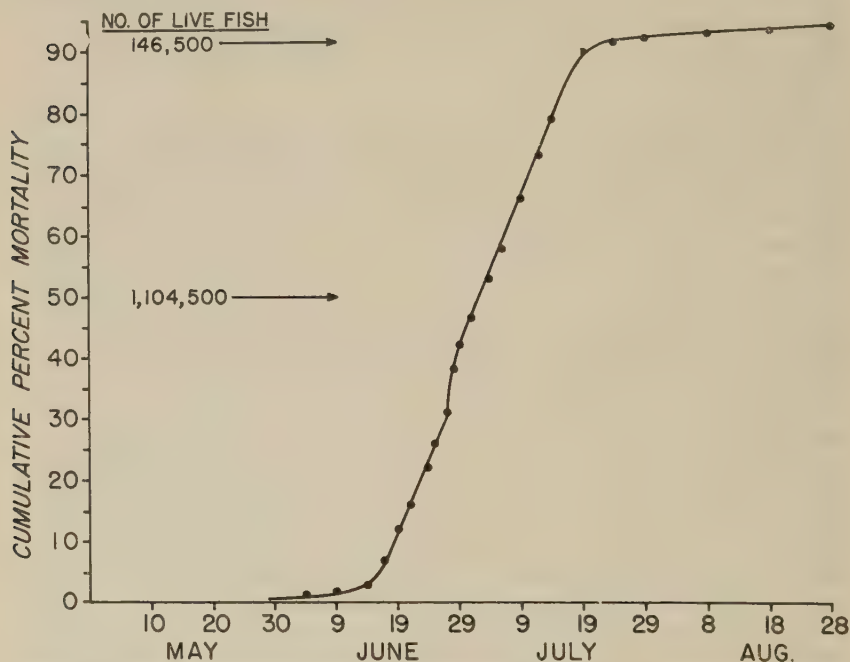


FIGURE 1.—Cumulative mortalities of all sockeye salmon at Leavenworth during the epizootic in 1952.

Twelve similar epizootics have occurred in the last 3 years in five of the seven hatcheries which have reared sockeye salmon in the State of Washington.

The pathology in all epizootics was similar or identical. Diseased fish were lethargic; hemorrhagic areas appeared at the base of the fins and in the isthmus; the stomach was distended and often filled with a milky fluid; the intestines were reddened and contained a straw-colored, watery fluid often tinged with blood; hyperemic areas were present in the air bladder, peritoneum, and fat; and spinal deformities developed among some of the fish that had survived the early stages of the epizootic.

No parasite was demonstrated in diseased fish nor were bacteria isolated that could be shown to cause the disease. Furthermore, fish inoculated with bacteria-free filtrates of moribund fish contracted the disease. The evidence obtained from our studies indicated that the disease was caused by a virus.

PREVENTION AND CONTROL

The prevention and control of virus diseases of fish presents a serious problem, since present-day chemotherapy is not efficacious. The measures used to prevent and control virus diseases in man have included immunization, the use of specific antisera, sanitation, elimination of vectors, and quarantine of infected individuals. Obviously, all of these methods are not feasible in the control of virus diseases in fish.

The only successful measures for prevention and control of virus diseases of fish have been the quarantine of stocks which were either infected or exposed to infection (Layman, 1949; Rucker *et al.*, 1953). The breeding of immune stocks of fish has also been successful (Layman, 1949). Layman selected carp for brood stock which had survived infectious dropsy disease and thus were thought to have a natural immunity. Mortalities were reduced from 60 percent to 4 or 5 percent after several years of selective breeding with this stock.

It is important in the prevention of a virus disease to determine the original source of infection. Food, water, animal vectors, and eggs from infected adults are possibilities. Snieszko (1953) has outlined measures to control virus diseases if they originate from the above sources.

Suggestive, but not conclusive, evidence by Roegner-Aust, Brunner and Jaxtheimer (1950) suggested the possibility that the virus of infectious dropsy disease of carp was transmitted through apparently healthy eggs. This possibility was considered in the Washington hatchery epizootics. Sockeye salmon became infected at one hatchery, but not at another hatchery, although the original source of eggs was the same for both hatcheries. This evidence tends to throw doubt on the possibility that eggs were responsible for the introduction of the disease in the Washington hatchery population. Likewise, epizootics occurred at hatcheries widely separated geographically and with different sources of water and food. All troughs in a given hatchery were not infected concomitantly, nor were adjacent ponds or troughs necessarily infected simultaneously. Wunder and Dombrowski (1951) reported on the transmission of infectious dropsy disease of carp by parasitic copepods and leeches. Attempts have been made to isolate the Washington hatchery virus directly from possible animal vectors as well as from food, water, eggs, and plant vectors. All experiments of this type thus far have been negative, but evidence does not preclude the presence of a virus in one or all of these sources. It must be recognized that the probability is slight of isolating a virus directly from these sources if the number of virus particles is small or irregularly distributed.

Hatchery records for the periods of epizootics showed that all diseased

TABLE 1.—*Synopsis of knowledge of virus diseases of fish*

Item	Virus disease						
	Lymphocystis	Fish pox	Lymphosarcoma	Papilloma	Infectious dropsy of carp	Disease in acara	Disease in sockeye salmon
Contagious from epizootological evidence	+	+	+	+	+	+	+
Experimentally transmitted with serial transfers	-	-	-	-	-	-	-
Filterable agent experimentally infectious	+	-	-	-	+	+	+
Inclusion bodies demonstrated	+	+	-	-	-	+	-
Demonstrated with electron microscope	-	+	-	-	+	-	-
Primarily proliferative	+	+	+	+	-	-	-
Primarily degenerative	-	-	-	-	+	+	+
Chronic	+	+	+	+	+	-	+
Acute	-	-	-	-	+	+	-

fish had been fed a similar fish-product diet. Hatchery fish which received a diet containing no fish products did not acquire the symptoms of the virus disease unless experimentally exposed to the disease. Thus, the practice of feeding untreated, raw fish products to hatchery-reared fish must be regarded with suspicion. This attitude was also recently expressed by Snieszko (1953).

Current experimental evidence gives little cause to believe that hatchery personnel spread the disease from trough to trough if sanitary precautions are enforced. Only a few fish in a given trough or pond seem to be infected directly from the original source, but these few diseased fish apparently infect the remaining healthy population with great rapidity. It is likely that by the time the disease is recognized in a trough, most of the population is infected.

Immunological, chemotherapeutical, and other remedial treatments are of value and should be investigated thoroughly. However, some of these methods, by their very nature can be evaluated only after several years of investigation. Immediate control of the epizootic in sockeye salmon appears to depend largely upon the prevention of the disease by the elimination of the original source of the virus.

Preventive and control measures for virus diseases of fish must await an intensive study of the diseases and their mode of transmission. As yet, evidence that viruses are agents causing many fish diseases is not conclusive (Table 1). Fundamental research is necessary to detect the source of infection, to define the manner by which the disease is transmitted, and to describe the pathological changes in infected fish.

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DEVELOPMENT OF DISEASE-RESISTANT STRAINS OF FISH

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ABSTRACT

Some of the achievements in selective breeding of animals for resistance to diseases are discussed. The literature on disease resistance among strains of trout within a species is reviewed. The known mechanisms of disease resistance are discussed in relation to the problem of creating maximum resistance through selective breeding.

A brief report is made on the results of the first 11 months of operation of a Dingell-Johnson project of breeding brook and brown trout for resistance to ulcer disease and furunculosis.

The variability of animal and plant species and the use of selective breeding to stabilize variants into widely different varieties and strains is well known. Outstanding examples of this process occur in fish as seen in the many varieties of goldfish which have been established by Japanese breeders, and in the profusion of color- and fin-forms which have been produced in some species of tropical fish.

This paper is confined to only one aspect of selective breeding, namely, breeding for resistance to disease. Embody and Hayford (1925) (see also Hayford and Embody, 1930) reported on a breeding program carried on for a number of years at the Hackettstown, New Jersey, hatchery. Davis (1946) briefly summarized breeding work done in several hatcheries where the emphasis, as in the work of Embody and Hayford, was not primarily on disease resistance. The writer knows of no sustained effort which has been made to improve fish in this respect. Scarcity of published reports, however, does not mean that nothing has been accomplished. A certain amount of selection is, without doubt, exercised by many trout-culturists at spawning time, and this, together with the natural elimination of the most susceptible individual fish before they reach spawning age, undoubtedly has resulted in greater disease resistance in hatchery stock than is present in wild stock.

The absence, up to now, of any sustained program of selective breeding should not be regarded as indicating a lack of interest on the part of fish-culturists. Such breeding of trout requires special facilities not available at a regular production hatchery, and these facilities are costly to construct. Wright (1951-52) has described excellently these difficulties, and has summarized the problem from a geneticist's view point.

Breeding for disease resistance has not, in general, been as extensive for animals as for plants. This does not reflect upon the suitability of animals for such genetic improvement, but rather has resulted from the ease with

which large domesticated animals can be treated individually. Veterinary science has advanced rapidly, and medical treatment of valuable animals has been so successful that there has been little demand for genetic improvement in resistance to disease. The fear is now expressed by veterinarians, as well as by physicians, that the very effectiveness of modern medicine may reduce natural or genetic disease resistance to a point where new dangers are created.

There has, of course, been a very widespread application of genetic methods in breeding the larger domesticated animals for improved performance along certain lines, or for greater conformity to arbitrarily defined breed characteristics. Efforts to improve the animal have been chiefly along what might be called "negative" lines, *i.e.*, to breed *out* certain undesirable traits or familial defects which have appeared from time to time. Among these might be mentioned hemophilia in dogs, cryptorchidism in pigs, and dwarfism in several breeds of cattle, particularly Herefords about which we hear so much at present. Some positive work has been done in California to establish resistance to brucellosis in swine.

It is quite certain that genetic resistance to disease exists in certain breeds, or individuals, of our larger domesticated animals. A striking illustration occurred in sheep in Iceland. The native sheep had been an isolated strain for many hundreds of years. These sheep were rather small, and there was frequent agitation to "improve" them through the importation of larger European breeds. Larger sheep were finally imported from Germany. The introduced animals, which appeared free from disease, proved to be carriers of infection for which the Icelandic sheep had no resistance. The result was a decimation of the native flocks from diseases which were so rare in Germany as to be almost unknown to German veterinarians. While the German sheep were disease resistant, they proved to be poorly adapted to the climate and feeding practices of Iceland, so that no benefit resulted from their importation.

With smaller domesticated animals and with laboratory animals, more has been done to breed for resistance to infection, and one gets a clear indication of what is possible in this field. As the individual value of an animal decreases and the numbers commonly dealt with increase, it becomes more important to use mass methods in handling them. With chickens, for instance, chemotherapy is used for entire flocks and mortality is further controlled by culling. The chicken is, however, well suited for breeding for disease resistance.

Roberts and Card (1935) selected chickens for resistance to pullorum disease. Their experiment continued for 10 years, and resulted in establishing strains highly resistant to *Salmonella pullorum*. They found this resistance to be inheritable, and dominant to susceptibility, with probably more than one pair of genes involved. Crosses between two resistant strains resulted in progeny with greater resistance than either parent strain. The blood of a resistant strain had a higher erythrocytic count and lower leucocyte count than that of the susceptible line.

Hutt and Cole (1947), by selective breeding over a period of 12 years,

developed two strains of white leghorns which were highly resistant and one strain which was susceptible to lymphomatosis, a virus disease. When the two resistant strains were crossed, the progeny were less resistant than either parent strain. This would indicate the resistance in the two strains to be due to different pairs of genes, and that resistance was also not completely dominant over susceptibility.

Cole (1950) later tested the three strains for resistance to a totally different disease, bluecomb, and found that the two lymphomatosis-resistant strains differed greatly in resistance to bluecomb, and that the lymphomatosis-susceptible strain was apparently immune to the malady. This illustrates the concept, now generally accepted, that there is no such thing as hereditary, general resistance to all infections, but that in all cases genetic resistance is specific to one particular disease.

A good general account of what is known of genetic aspects of mortality in the fowl is contained in "The Genetics of the Fowl," by F. B. Hutt (1949). Parts of this book might well be read by anyone interested in the breeding of disease resistant fish. The author's arguments for a genetic attack on the problem of disease in chickens apply with equal force to diseases in trout.

Among laboratory animals more work has been done with mice than with any other form. Many strains have been bred resistant to a number of bacterial infections. A comprehensive summary of the genetic work with mice has been made by Grüneberg (1952), who includes a case of inherited difference in susceptibility to infection with a tapeworm. Even the honey bee has been investigated, and a strain has been found which, because of its superior housekeeping, is less subject to foulbrood. The passion for cleanliness is, in this case, hereditary. There have been a few published reports on differences in disease resistance among strains of trout. Wales and Evins (1937) presented data for three strains of rainbow trout which showed differences in susceptibility to mechanical irritation of gills by suspended particles in the water. Davis (1946) mentioned differences in mortalities in various strains of hatchery-reared brook trout. The writer (Wolf, 1941) published a brief note regarding differences in resistance to ulcer disease in six strains of brook trout, and reported (Wolf, 1942) that two strains of rainbow trout differed markedly in showing injury from lack of vitamin B₁ in the diet. Additional evidence that trout are well adapted for genetic selection appears in a later paragraph.

Establishing disease-resistant strains of any of the domesticated animals is a worthy achievement, and is for the fish-culturist a sufficient goal. Grüneberg (1952) has appropriately stated that, "The discovery that resistance or susceptibility is genetic remains barred unless the physiological channels are known by means of which differences are brought about. Once these mechanisms are clear, the way is open for therapeutic measures." Many current investigations are concerned with the mechanisms of genetic resistance to disease.

Nothing like a complete list of the factors within the host which affect resistance to disease could be made at present. New discoveries are being

made as a result of great activity in such fields as nutrition, physiology, and biochemistry. Some of the factors listed below have been mentioned in the literature but have never been subjected to critical experimentation; others have been studied in some detail; all probably have a genetic basis.

1. Barrier action of the skin and mucus membranes. In the case of fish the mucus itself is commonly supposed to have a protective function against invasion by infective agents.
2. Destruction of foreign organisms by gastric and intestinal secretions.
3. Number and activity of blood leucocytes.
4. Number of erythrocytes in blood.
5. Ability of macrophages to digest phagocytized bacteria.
6. Bactericidal properties of blood serum.
7. Presence of natural antitoxins.
8. Ability to form antibodies.
9. pH of blood.
10. Detoxifying activity of the liver.
11. Efficiency in absorption and metabolism of certain vitamins, or other food-factors, involved in any of the above agencies.

The complications in the relationships between resistance factors are indicated in the work of Weir (1949) and Weir, Cooper, and Clark (1953) who found that in certain strains of mice selected for resistance to *Salmonella typhimurium* the leucocyte count and blood pH were positively correlated with resistance. When, however, strains were selected on the basis of leucocyte count and pH of blood, and were then subjected to infection with the same organism, no positive correlation was found.

One reason for listing some of the host factors which may affect genetic resistance to disease is to emphasize that in any one case many mechanisms may be, and usually are, implicated. If only a single character, depending on a single pair of genes, were involved, it would be a simple matter to establish a pure, or homozygous, strain, and this strain could be maintained pure and undefiled to transmit its characteristics to all its progeny. But where many factors operate, and probably most of them depend on several pairs of genes, it becomes almost impossible to establish a pure line. Thus, while it is fairly certain that any intelligent program of breeding for resistance to disease should accomplish something, it is also fairly certain that such a program should continue as long as the art of fish culture is practiced. Reversion is likely to occur when selection practices are abandoned.

No absolute resistance or immunity to any disease natural to a species has yet been established through genetic selection. Resistance has been greatly increased, but never yet made absolute. One reason for this may lie in the failure to use at all times the most virulent strains of organisms for challenging the breed lines, but another reason lies in the multiplicity of mechanisms and of genes involved in resistance to infection.

A selective breeding project on trout has been in progress at Rome, New York, for one year. While the fish have not yet reached maturity some in-

TABLE 1.—Percentage monthly mortality of brown trout, from ulcer disease and furunculosis

Month	Mean water temperature (° F.)	Lot						Average
		A	B	C	D	E	F	G
Sept.....	58.8	0.1	0.3	0.9	0.0	0.1	0.5	35.6
Oct.....	52.2	2.8	1.2	4.6	0.9	1.1	3.1	1.1
Nov.....	48.4	0.4	0.5	0.2	0.3	0.5	0.3	0.3
Dec.....	38.4	0.2	0.3	0.1	0.2	0.0	0.0	0.1
Jan.....	36.7	0.2	0.4	1.0	0.3	0.4	0.0	0.3
Feb.....	37.5	0.1	1.2	0.9	0.8	1.8	0.0	0.7
Mar.....	38.7	0.0	4.8	0.9	1.1	0.7	0.0	1.1
Apr.....	45.0	0.4	8.4	0.4	2.4	0.4	0.0	1.7
May.....	49.1	1.0	11.1	0.9	1.4	5.6	0.0	3.0
June.....	56.3	17.5	25.0	47.1	10.2	41.6	14.3	23.2
July.....	59.6	37.1	47.7	29.0	27.6	27.8	22.2	30.7
Total.....	....	50.8	61.7	65.8	39.7	60.2	35.7	55.4

¹ Lot G omitted from average for September because mortality was chiefly from gill disease

TABLE 2.—Percentage monthly mortality of brook trout, from ulcer disease and furunculosis

Month	Lot											Average
	A	B ²	C ²	D	E	F	G	H	I	J	K	
Sept.....	4.9	1.2	0.3	17.0	1.0	0.1	0.0	1.0	0.0	0.0	0.0	2.3
Oct.....	11.2	70.5	94.9	77.6	0.0	2.3	6.3	24.0	0.7	5.1	4.7	27.0
Nov.....	0.5	16.9	32.8	2.5	0.0	50.5	27.9	26.6	2.9	1.2	11.6	15.8
Dec.....	0.1	2.4	10.3	1.5	0.0	18.3	3.8	4.7	6.7	0.7	6.7	5.0
Jan.....	0.0	1.6	2.9	0.5	0.0	7.0	3.3	3.2	8.3	0.6	6.5	3.1
Feb.....	0.0	1.3	0.0	1.6	0.0	2.4	1.4	1.6	12.2	0.3	7.7	2.6
Mar.....	0.2	0.0	0.0	1.6	0.0	3.0	1.6	0.7	12.7	1.6	8.8	2.7
Apr.....	0.8	0.4	8.8	2.7	0.0	2.3	0.5	0.7	19.6	3.7	16.5	5.1
May.....	0.8	0.0	3.2	4.4	0.0	23.5	1.3	3.8	20.5	5.5	15.5	7.1
June.....	1.7	10.1	6.7	9.2	0.5	64.8	32.0	72.9	41.7	36.9	28.8	27.7
July.....	6.3	58.0	0.0	35.0	3.9	95.1	25.9	77.9	37.1	50.5	21.7	41.1
Total.....	24.1	91.5	97.8	90.6	5.3	99.6	69.8	97.2	85.2	74.2	75.6	....

¹ Water temperatures same as in Table 1² Lots B and C were same strain, but from different hatcheries

formation is pertinent. During September, 1952, 11 lots of brook trout (*Salvelinus fontinalis*) and 7 lots of brown trout (*Salmo trutta*) fingerlings were collected from all the northeastern states. With a single exception all lots were from broodstock which had existed as separate, inbred strains for at least 8 years—though in most cases the lines ran back much longer.

These fish have been maintained in separate enclosures, fed the same diets, and as nearly as possible kept under the same conditions as regards crowding, water supply, and accessibility to infection with furunculosis and ulcer disease. The fish were exposed to both diseases simultaneously. Every effort was made to spread the infections and to present the same chance of contagion to all lots. Bacteriological cultures were isolated at frequent intervals to verify the presence of the diseases. Moribund fish, fin-clipped for identification, were spread around in all the lots. Fish which died from the diseases were ground up and fed to all the lots.

In Table 1 and 2 are presented the percentage mortalities to August 1, 1953. Not all the mortalities were from furunculosis and ulcer disease, as at one period shortly after the arrival of the fish, bacterial gill disease exacted quite a toll. This was the chief cause of the high loss during the month of September in lot G (Table 1). Treatments for this disease were purposely withheld. By far the greater part of the losses, however, was caused by furunculosis and ulcer disease. Although both infections were present at all times, none of the brown trout ever exhibited symptoms of ulcer disease, and the causative organisms of this disease were recovered only from the brook trout.

The data show that water temperatures were the controlling factor in losses from disease in all lots. They also indicate that considerable variation exists in resistance to ulcer disease and furunculosis among strains of trout, especially brook trout. This variation affords material for genetic selection.

This review of some of the results which have been achieved in breeding animals for resistance to disease indicates that the method offers great possibilities, but truly useful results cannot be expected in a short time. Convincing evidence exists that genetic resistance to bacterial infection in trout can be increased through controlled breeding, and it is hoped that the present project can be continued for a sufficient number of years to establish a high degree of resistance to two of the most troublesome bacterial diseases. It should then be possible to eliminate the present use of chemotherapeutic methods of control which are costly and not always successful.

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Part 111
Business Sessions

THE AMERICAN FISHERIES SOCIETY

EIGHTY-THIRD ANNUAL MEETING

The eighty-third annual meeting of the Society was opened in the Hotel Wisconsin, Milwaukee, Wisconsin, on Wednesday, September 16, 1953. The agenda were as follows:

Wednesday, September 16

Morning and Afternoon: Demonstration of underwater television, followed by a "Great Lakes Fish Boil".

Evening: Annual joint banquet—Circus Room, Hotel Wisconsin.

Thursday, September 17

Morning: Address by the President; roll call of members; action on nominations for membership; introduction of noteworthy guests and visitors; address by The Honorable John L. Farley, Director, U. S. Fish and Wildlife Service; appointment of sessional committees; reports of officers, chairmen of regional divisions, standing committees, and special committees.

Afternoon: Presentation and discussion of papers.

Friday, September 18

Morning: Presentation and discussion of papers.

Afternoon: Presentation and discussion of papers; reports of sessional committees; installation of the new President; concluding business.

REGISTERED MEMBERS IN ATTENDANCE

Adams, Arthur K., Calif.
Aldrich, A. D., Okla.
Allen, Walter M., Mont.
Allison, Leonard N., Mich.
Apelgren, Bert, Wis.
Armbruster, Daniel C., Ohio
Armstrong, G. C., Ont.
Atton, F. Mervyn, Sask.

Bagley, Lester, Wyo.
Bailey, Reeve M., Mich.
Bailliere, Lawrence, Mo.
Balch, Howard K., Wis.
Baxter, George T., Wyo.
Baxter, William, Del.
Beatty, Robert O., Ore.
Berquist, Howard, Wis.
Billy, George, Ohio
Bode, I. T., Mo.
Bradford, Arthur D., Pa.
Braker, William P., Ill.
Brasch, John G., Wis.
Brehmer, Morris L., Ill.
Brower, Alfred D., Mich.
Brown, C. J. D., Mont.
Brown, Henry H., N. M.
Burdick, George E., N. Y.
Burner, Charles C., Kas.
Burriss, Ralph M., Mo.
Butler, George Edward, Man.
Butler, Robert L., Minn.
Byrd, I. B., Ala.

Calhoun, Alexander J., Calif.
Carlander, Kenneth D., Iowa
Chapman, Charles R., Ohio
Chapoton, Robert B., Mich.
Christensen, Kenneth E., Mich.
Christenson, Lyle M., Wis.
Churchill, Warren, Wis.
Chute, Walter H., Ill.
Clark, Clarence F., Ohio
Clark, Minor E., Ky.
Clark, O. H. Jr., Mich.
Cleary, Robert E., Iowa
Clothier, William D., S. D.
Cooper, Edwin L., Wis.
Cooper, Gerald P., Mich.
Cornell, James H., N. C.
Cottam, Clarence, D. C.
Cramer, H. T. J., Wis.
Cuerrier, J. P., Ont.
Cummins, Robert Jr., Ohio

Daly, Russell, Wis.
Davis, George W., Vt.
Dendy, Jack S., Ala.
Dequine, John F., Fla.
de Roth, Gerardus C., Mich.
Dobie, John, Minn.
Domogalla, Bernhard, Wis.
Donaldson, Lauren R., Wash.
D'Sinter, Herbert F., Ill.
Dunham, Donald K., Wis.

Elder, David E., Ill.
Elser, Harold J., Md.
English, Thomas S., Wash.
Erickson, James G., Kan.
Erkkila, Leo, Mich.
Eschmeyer, Paul H., Mich.
Eschmeyer, R. William, D. C.

Fallis, Howard J., Wis.
Farley, John L., Va.
Ferguson, Robert G., Ont.
Foster, Richard F., Wash.
Fraser, James M., Ont.
Fritz, Raymond L., Mich.
Fukano, Kiyoshi G., Mich.

Galbraith, Merle G. Jr., Mich.
Gentry, Glenn, Tenn.
Gerking, Shelby D., Ind.
Gernes, Charles H., Iowa
Gibbs, Robert C., Mo.
Gordon, Seth, Calif.
Gottschalk, John S., Va.
Gowing, Howard, Mich.
Grassl, Edward F., Mich.
Greene, A. F. C., Wyo.
Gunter, Gordon, Texas
Gutermuth, C. R., D. C.

Hale, John G., Minn.
Hall, Gordon E., Okla.
Hansen, Donald F., Ill.
Harkness, William J. K., Ont.
Harmic, Jay L., Del.
Harris, Richard F., Wis.
Harth, William J., Ill.
Hasler, Arthur D., Wis.
Hayford, Charles O., N. J.
Heding, Robert B., Wis.
Hennemuth, Richard C., Iowa
Herman, Elmer, Wis.
Herrington, William C., Va.

Hile, Ralph, Mich.
Hogan, Joseph R., Ark.
Hooper, Frank F., Mich.
Hubbs, Clark, Texas
Hunt, Burton P., Fla.
Hunt, Douglas, Wis.
Hunter, R. P., Conn.

Jackson, Samuel W., Okla.
Janzen, Daniel H., Minn.
Jenkins, Robert M., Okla.
Jergens, Glenn D., Wis.
Johnson, Leon D., Wis.
Johnson, Raymoond E., Minn.
Joslin, Verne E., Minn.

Katz, Max, Ohio
Kennedy, W. A., Man.
King, John, Okla.
Kingsbury, Oliver R., N. Y.
Kittel, Hartford, Minn.
Klick, Thomas A., Wis.
Klingbiel, John H., Wis.
Kmiotek, Stanley, Wis.
Krumholz, Louis A., Tenn.
Kutkuhn, Joseph H., Iowa

Langenfeld, Edwin P., Wis.
Larkin, Peter A., B. C.
Lawrence, William M., N. Y.
Leonard, Edgar M., Okla.
Leonard, Justin W., Mich.
Lloyd, Charles N., Wis.
Loftus, Kenneth H., Ont.
Lopinot, Alvin, Ill.
Lutwitz, Lawrence E., Wis.

MacDonald, A. H., Sask.
MacKay, H. H., Ont.
Maloney, John E., Minn.
Mansueti, Romeo, Md.
Meehan, O. Lloyd, D. C.
Miller, Lawrence F., Ala.
Miller, Richard B., Alta.
Miller, Sidney C., Wis.
Moffett, James W., Mich.
Morehouse, L. E., Wis.
Morgan, H. R., N. D.
Moyle, John B., Minn.
Mraz, Don F., Wis.
Muench, Bruce, Ill.

Needham, Paul R., Calif.
Niemuth, Wallace E., Wis.

O'Donnell, D. John, Wis.
Oehmcke, Arthur, Wis.

Olson, Donald E., Minn.
Omstead, Duane H., Ont.
Owen, Edward E., Wis.
Owen, John B., Iowa

Paloumpis, Andreas A., Iowa
Parr, Sam, Ill.
Parsons, John W., Tenn.
Patterson, Matt, Wis.
Pautzke, Clarence F., Wash.
Pelton, John Z., Ohio
Phenicie, Charles K., Mont.
Phillippy, Clayton, Ill.
Posekany, Lewis, Wis.
Pritchard, A. L., Ont.
Probst, Robert T., Wis.

Reid, Cecil W., Texas
Reid, Kenneth A., N. Y.
Rick, Alan J., Minn.
Roach, Lee S., Ohio
Rosebery, Dean A., Mo.
Rubin, Mrs. Nell R., Ill.
Rucker, Robert R., Wash.
Ruhr, Clifford E., Tenn.
Rutherford, Robert M., D. C.

Schafer, Harry E., Jr., La.
Schneberger, Edward, Wis.
Schoonover, Roy E., Kan.
Schumacher, Robert E., Minn.
Seaman, Elwood A., W. Va.
Shelly, James N., N. Y.
Shetter, David S., Mich.
Shoemaker, Carl D., D. C.
Simpson, James C., Idaho
Skiff, J. Victor, N. Y.
Smith, Bernard R., Mich.
Smith, Spencer H., Miss.
Smith, Stanford H., Mich.
Snieszko, Stanislas F., W. Va.
Sowards, Charles L., Wyo.
Speaker, E. B., Iowa
Sprecher, G. E., Wis.
Stauffer, Thomas M., Mich.
Steinbach, Frank C., Ohio
Stevens, Richard I., Wis.
Stroud, Richard H., D. C.
Swanson, Henry I., Minn.
Swenson, Hjalmar, Minn.
Swift, Ernest, Wis.
Swift, Lloyd W., D. C.
Swingle, H. S., Ala.

Tack, Peter I., Mich.
Tait, Howard D., Mich.
Tanner, Howard A., Colo.

Taube, Clarence M., Mich.
Taylor, V. R., Ont.
Tennant, Donald L., Ohio
Terrell, Clyde B., Wis.
Tetzloff, Clifford L., Mich.
Thompson, Frederick A., N. M.
Thompson, Paul E., D. C.
Thompson, William H., Okla.
Thorpe, Lyle M., Conn.
Threinen, Charles W., Wis.

Van Deusen, R. D., Md.
Van Oosten, John, Mich.
Ver Duin, Claude, Mich.
Viosca, Percy Jr., La.
Voskuil, Glenn, Wis.

Wade, Gerry, Maine
Walker, Charles R., Mo.
Walker, Gene Ward, Ill.
Walker, John D., Ohio
Wanie, Barney, Wis.
Wells, LaRue, Mich.
Werner, W. H. R., Ont.
Whitacre, Maurice A., Ill.
Wilkinson, J. T., Mich.
Wirth, Thomas L., Wis.
Wistrom, Clarence A., Wis.
Wohlschlag, Donald E., Calif.
Wolf, Louis Edward, N. Y.
Wright, Stillman, D. C.

OPENING REMARKS OF THE PRESIDENT

STATUS AND FUTURE OF THE AMERICAN FISHERIES SOCIETY

RALPH HILE

I can think of no more fitting theme for the opening remarks of this, our Eighty-third Annual Meeting, than an appraisal of the status of our organization and comments on the means whereby that status may be improved for our common benefit.

During the past year or so criticism of the American Fisheries Society has been much in vogue. To a large extent the criticism has been healthy in that the critics focused attention on certain weaknesses in our structure and function, proposed methods for their elimination, and offered assistance in bringing about improvement. This attitude speaks well for the future of our organization. It demonstrates an interested membership—a membership that senses the possibilities of our Society and is determined to see them realized. Without alert and active members no organization can hope to progress.

Do not misunderstand me—not all criticism has been healthy or helpful. We have heard also the raucous voices of the generalized complainers—those spiritual hypochondriacs who seek no goal but are merely fascinated by the melody of their own flatulence. I should not trouble to mention this insignificant minority did I not feel that even they can be redeemed. To those few that are tempted to seek progress by urging others to work harder and improve their ways may I offer the observation that payment of dues does not carry with it a grandstand seat and the privileges traditionally appurtenant thereto; rather, it makes you one of a team—a team that needs your help and will succeed or fail according to the way its members play the game.

Despite a sprinkling of chronic malcontents all indications point toward a new and better era in our Society's affairs. Our membership is at a record level, our finances are sound, and, what is more important, we find a heightened interest in our organization's activities. To the end that this newly found energy may be gainfully applied and not be dissipated futilely it is well for us to inquire into our structure and into our program.

One immediate problem concerns changes in our constitutional organization and procedures that may promote efficient operation and make for a wider participation of members in the Society's affairs. Such questions as these occur. Should officers be elected by a general ballot distributed to all members? Should procedures for the amendment of the Constitution be simplified? (Here I may mention that one of the two procedures now available has proved impractical and the other rather cumbersome.) Have some of our Standing Committees outlived their usefulness so far that they should be discontinued? Do we need new Standing Committees designed to meet new needs of the Society? Should our Executive Committee—which now numbers 17 members and increases as new Regional Divisions

and new Standing Committees are established—be streamlined to provide a less cumbersome working group? Shall traditions have equal standing with our Constitution and By-Laws or should they be either discarded or given legal status? Some of the questions I have given have long needed consideration; some will be brought before the present meeting for decision. Others may be raised during our sessions.

Development of a more democratic and smoothly working organization is, of course, not a goal in itself. Our true goal is a more useful organization. Our major problem, accordingly, is one of making our program most effective with the resources at our disposal.

Our principal resource is our membership. Defective as our recruitment may have been in certain areas, we still number in our ranks a high percentage of all professionals in the fishery field—administrators, research and management biologists, fish-culturists, technologists—and in addition have the support of many individuals and organizations with interest in sport and commercial fisheries. The array is impressive; no other organization on our Continent can speak so authoritatively in matters relating to the fisheries. Our views and recommendations should carry weight; they will if properly publicized.

A surely valid criticism of our Society hinges on our failure to make our influence felt as greatly as it should be on important questions of policy and program. Too frequently the most praiseworthy resolutions and other statements of opinion have been approved at our meetings never to be heard from or seen again until printed many months later in the *TRANSACTIONS*—an excellent volume but one of limited distribution. True, we frequently instruct our Secretary to forward copies of resolutions to Cabinet members, Chairmen of various legislative committees, and other officials, and our North American Fish Policy—long since overdue for revision—received widespread distribution and use. Yet, in the main, our record for throwing our influence where it could best serve the welfare of the fisheries has not been good.

If we wish to have our Society more influential in the framing of policies and programs we need only to establish the proper mechanisms. A first and an excellent step was taken when we affiliated with the Natural Resources Committee, but additional action may be required. Possibly we should re-define the status and duties of our Publicity Committee, now concerned principally with local publicity on our Annual Meeting, and charge it with the responsibility for appropriate dissemination of records of action. When we have taken a considered stand on a matter of national or international concern we need not hide it between the covers of the *TRANSACTIONS* or at most impart our views to two or three selected officials. We can, if we wish, have copies or digests of actions distributed as needed—to all interested officials and organizations, to news agencies, to publishers of publicly and privately sponsored journals. Perhaps we should go further and establish a carefully selected committee or board with power to speak authoritatively for the Society in matters that arise between meetings.

Once we undertake to wield greater influence in fishery matters, we must, of course, assume responsibility for the soundness of our actions. We should have no place for fanaticism, espousal of questionable fads, or the promotion of extreme and biased points of view. On the other hand, we should be uncompromising in our demands for sound fishery programs—programs carefully planned, conducted along established principles, adequately supported, and executed by properly trained and decently compensated personnel.

We can do well also to wage battle against superficiality, a major curse of our profession, and the ineffectiveness that inevitably follows in its train. We have brought this plague upon ourselves by harboring the foolish notion that research into the fundamentals of aquatic biology—inquiry into how fish and associated organisms live—is impractical, preferably to be avoided as a senseless luxury and to be kept to a minimum when unavoidable. This misconception of the role of basic research and a mania for action have betrayed us into rushing headlong into management programs for which the needed background of knowledge was lacking. Naturally enough the results frequently have been all too disappointing. I do not wish to imply that all action should be deferred until long and tedious investigations have been completed. I would like to emphasize, nonetheless, that until as a matter of general policy, research is made the basis of management practices attempted and the means of determining their results, the effectiveness of our management programs will not be commensurate with the amounts invested and discredit will fall on administrator and biologist alike.

We can give our campaign for greater soundness in fishery programs important support in our meetings and publications. Those who accept responsibility for drawing up programs should arrange for substantial and stimulating talks and discussion periods. Our editors in their selection of materials for publication should strive for even higher standards of excellence. Our national meeting in particular should be so planned along broad lines as to be of greatest benefit to all in attendance. I fear that we have been slow in adjusting the program of our national meeting to the changed conditions that followed regionalization. This year's program represents an attempt at this adjustment. Our Program Chairman has devoted much time, thought, and effort to its preparation. I am sure that he and his successor both will appreciate greatly your comments and suggestions.

The American Fisheries Society belongs to, is made up of, all of its members—the disgruntled as well as the contented. Its future will be determined by them. Its accomplishments will be limited only by their interest and effort.

APPOINTMENT OF SESSIONAL COMMITTEES

Nominating

Shelby D. Gerking, Indiana, *Chairman*
George E. Butler, Manitoba
Minor E. Clark, Kentucky
Clarence F. Pautzke, Washington
Gordon L. Trembley, Pennsylvania

Resolutions

Stillman Wright, District of Columbia, *Chairman*
W. Mason Larence, New York
Richard B. Miller, Alberta
William F. Sigler, Utah
Lloyd L. Smith, Jr., Minnesota

Auditing

Clark Hubbs, Texas, *Chairman*
Kenneth D. Carlander, Iowa
E. A. Seaman, West Virginia

Time and Place

Louis A. Krumholz, Tennessee, *Chairman*
John F. Dequine, Florida
Lauren R. Donaldson, Washington
Harold J. Elser, Maryland
Lee S. Roach, Ohio

Publicity

Walter E. Scott, Wisconsin, *Chairman*
Edwin L. Cooper, Wisconsin
Elmer Herman, Wisconsin

REPORT OF OFFICERS

REPORT OF SECRETARY-TREASURER

GEORGE E. SPRECHER

This is the fifth and final report of my activities as Secretary-Treasurer of the American Fisheries Society. I have been extremely fortunate to have served the Society during a period when its growth both financially and from the standpoint of membership has been greatest. I believe that it is entirely in order at this time to provide you with a brief five-year review of the highlights responsible for the success of your organization.

Financially, the Society is in excellent condition. At the close of business on June 30, 1953 an independent certified public accountant, John L. Okey, was employed to audit the books of the Society for the five-year period. Briefly, a summary of the audit shows that on June 30, 1953 the general fund showed a cash balance of \$3,980.12. The permanent fund showed a cash balance of \$213.67 and securities with a cash value of \$11,716.00. Incidentally, all but \$1,289.00 of these securities are in U. S. government bonds.

Your attention is called to the fact that only one major liability must be paid from the funds on hand. That is the cost of Vol. 82 which has just been mailed to members. On this basis the Society now has a net worth in excess of \$10,000.

Any consideration of the forward strides made by the Society during the past five years immediately reminds us of the outstanding individuals who served the Society as officers and committee members during this period. I ask your indulgence while I remind you of a few men who have greatly advanced the prestige of this organization.

The first President under whom I had the honor to serve was Seth Gordon. Immediate steps were taken to modernize the administration of the business of the Society. Three general letters were sent to members during the year to advise them of the work being done by the officers and various committees. Past due accounts in the amount of \$1,191.00 were collected. Insurance on library property was obtained. An entirely new bookkeeping system was developed and over 300 new members were accepted.

During this period Ralph Hile took the responsibility of editing the delinquent issues of the *TRANSACTIONS* so that the new editor could start work on the current issue.

In 1949 Milton C. James became President of the Society. Both the membership of the Society and its financial condition improved considerably during that year. President James popularized the Society by his promotion of every branch of the fisheries and not just any one group or segment of fisheries workers. A new Constitution and By-laws drafted by

Jack Deason and his committee was adopted at this time and the Western Division of the Society began functioning as a distinct unit.

Albert S. Hazzard became President of the Society in 1950 and inaugurated a number of practices which have been of great value to the Society. He was the first President to attend the annual meeting of a Division. He arranged the joint meeting of the American Fisheries Society and the American Society of Limnology and Oceanography which was held in Rochester, N. Y. He extended the time available to the Nominating Committee to study candidates for offices and committees by appointing the committee in June. Our finances and membership continued to improve under the presidency of Al Hazzard.

In September of 1951 Bill Harkness was elected President. Probably the most outstanding work done by the new President was to popularize the Society throughout the Canadian provinces and to cement better international relations on all fisheries matters. By September of 1952 the membership of the Society reached the unprecedented high of 1,469 members. The *TRANSACTIONS* were published on time and the financial condition of the Society remained excellent.

The activities of the current President of the Society, Ralph Hile, are too recent and too extensive for me to attempt to describe them here. He has fulfilled the duties of the President far beyond the call of duty. He has worked tirelessly to bring before the Executive Committee and the members, suggested needed changes in the Constitution and By-laws.

It is not at all unbelievable that because of the services rendered the Society by these distinguished presidents that our membership now totals 1,513. This roster compares very favorably with a membership of 806 in September of 1948.

I would be remiss in my duty to the Society if I failed to mention certain individuals who have aided the Society beyond expectations during my five-year tenure of office. First, I would like to call your attention to the efforts of Dr. W. C. Beckman, Librarian. Bill maintained our library at a high standard and sold more than \$8,500 worth of publications in five years. He has kept accurate records and merits your sincere gratitude.

Ernest Swift, Director of the Wisconsin Conservation Department, has provided clerical and accounting services to the Society to the extent that our total costs for such services for five years amounted to less than \$625.00.

Last, but not least, I wish to call your attention to the unselfish devotion to the Society of Miss Ann Zweck who has performed the clerical work of the Society in addition to her regular duties as my secretary. Her attendance at these annual meetings has cost her a corresponding amount of vacation time.

REPORT OF RECEIPTS AND DISBURSEMENTS

July 1 1952 to June 30, 1953

GENERAL FUND

Balance on hand, July 1.....	\$ 7,972.47
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Receipts:

Annual Dues

Individuals

For the year 1949-50	\$ 9.00	
1950-51	49.50	
1951-52	305.95	
1952-53	4,527.15	
1953-54	75.40	\$ 4,967.00

State Memberships

For the year 1952-53	\$1,440.00	
1953-54	40.00	\$ 1,480.00

Library Memberships

For the year 1950-51	\$ 8.00	
1951-52	28.00	
1952-53	308.00	
1953-54	28.00	\$ 372.00

Club Memberships

For the year 1951-52	\$ 10.00	
1952-53	235.00	\$ 245.00

Sale of Transactions and Special Publications	\$ 995.50
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Refund on Insurance	28.92
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Plus: Total Receipts	\$ 8,088.42
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Balance, July 1, Plus Total Receipts	\$16,060.89
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Disbursements:

Printing of transactions	\$ 5,135.90
Other printing	379.37
Clerical services—Ann L. Zweck	152.42
Postage and supplies	176.33
Editing	100.00
Reporting services	185.00
Insurance	48.44
Fidelity bond	18.75
Travel expenses—Ralph Hile	192.61
Refund of annual dues	1.00
Dues to Natural Resources Council	50.00
Petty cash fund deposits	101.20
Miscellaneous	26.80

Less: Total Disbursements	\$ 6,567.82
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Transfer to Permanent Fund, Sept. 1952	5,500.00
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Gross Balance, General Fund, June 30, 1953	\$ 3,993.07
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Less: Bank debit memos, etc.	12.95
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Net Balance, General Fund, June 30, 1953	\$ 3,980.12
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PERMANENT FUND

Balance on hand, July 1, 1952 \$ 387.57

Receipts:

Dividend Income
 Consumers Power Company\$ 57.40
 Central Illinois Light Company 13.20
 Mortgage Certificates
 Income distribution 12.81
 Sale of stock distribution rights 2.69

Plus: Total Receipts \$ 86.10
 Transfer from General Fund, September 1952 5,500.00

Balance, July 1, Plus Receipts and Transfer \$ 5,973.67

Disbursements:

Purchase of government saving bonds\$ 5,760.00
 Less: Total Disbursements \$ 5,760.00

Net Balance, Permanent Fund, June 30, 1953 \$ 213.67

RECAPITULATION

Net Balance, General Fund, June 30 \$ 3,980.12
 Net Balance, Permanent Fund, June 30 213.67

Net Balance, Both Funds, June 30 \$ 4,193.79

SECURITIES HELD, JUNE 30, 1953

- | | |
|---|---------|
| (1) New York Title and Mortgage Co., Serial F-1 | Paid in |
| Certificate No. 10811 | full |
| (2) Title Guarantee and Trust Company | |
| Certificate No. 103553 | Paid in |
| Certificate No. B-71070 | full |
| (3) U. S. Government Savings Bonds | |

<i>Number</i>	<i>Date Purchased</i>	<i>Mature Value</i>	<i>Value</i>
D682395F	8/29/49	\$ 500	\$ 400
M1610061F	8/29/49	1000	800
D702345F	12/15/50	500	385
M1703542F	12/15/50	1000	770
M1773328F	10/31/51	1000	760
M1773329F	10/31/51	1000	760
M1773330F	10/31/51	1000	760
M18441J	9/26/52	1000	724
M18346J	9/26/52	1000	724
M18347J	9/26/52	1000	724
M18348J	9/26/52	1000	724
M18349J	9/26/52	1000	724
M18350J	9/26/52	1000	724
M18351J	9/26/52	1000	724
M18352J	9/26/52	1000	724
		\$ 14,000	\$ 10,427

(4) Consumers Power Company	
No. G-6085, 28 shares at 38	\$ 1,064.00
(5) Central Illinois Light Company	
No. B-1752, 6 shares at 37½	225.00
Total	<u>\$11,716.00</u>

PROPOSED BUDGET FOR 1953-1954

GENERAL FUND

Balance on hand July 1, 1953	\$ 3,980.12
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Estimated Receipts

Annual Dues	\$ 8,000.00
Sale of publications	<u>1,000.00</u>
Total Estimated Receipts	9,000.00
Net Estimated Income	<u>12,980.12</u>

Estimated Disbursements

Printing of Transactions—Volume 82	\$ 5,200.00
Printing of Transactions—Volume 83	5,200.00
Other printing	500.00
Clerical services	175.00
Postage and supplies	200.00
Editing	100.00
Reporting services	200.00
Insurance	50.00
Fidelity bond	18.75
Travel expense	250.00
Index preparation	100.00
Dues—Natural Resources Council	50.00
Miscellaneous	<u>250.00</u>
Total estimated disbursements	<u>\$12,293.75</u>
Net Estimated General Fund Balance, June 30, 1954	686.37

PERMANENT FUND

Balance on hand July 1, 1953	\$ 213.67
Value of securities held July 1, 1953	11,716.00

Estimated Receipts

Dividends	\$ 70.60
Increment on U. S. government bonds	<u>173.00</u>
Net Estimated Permanent Fund Balance, June 30, 1954	<u>\$12,173.27</u>
Net Estimated Balance, Both Funds, June 30, 1954	<u>\$12,859.64</u>

REPORT OF THE LIBRARIAN

HOWARD A. TANNER

Since Dr. Beckman could not attend our meetings this year he has asked that I present the Librarian's report for the period of September 1952 to June 1953 in which he served as Librarian as well as for the brief period I have served as your Acting Librarian.

In December, 1952, the library received 640 copies of Volume 81. In June, 1953, several miscellaneous volumes were received from Mr. George Sprecher. A few copies of the early 1940's were included and have been distributed to the library or to individuals teaching fisheries courses.

During the year 320 volumes of the *TRANSACTIONS*, 11 copies of the index, and 127 copies of *A List of the Common and Scientific Names of Fishes of the United States and Canada* were sold. The receipts have been forwarded to your Secretary and he has reported on the amounts.

The last volume for the year 1926 was sold out during the year.

Dr. Beckman has asked me to report that he is continuing the work of the cumulative index for 1929—1951 volumes.

As of September 1, 1953, there were 5,768 volumes on hand, with a total list value of \$16,277.25.

REPORT OF THE CHAIRMAN OF THE
NORTHEASTERN DIVISION

GORDON L. TREMBLEY

The second annual meeting of the Northeastern Division was held jointly with the ninth annual meeting of the Northeast Section of the Wildlife Society at Mount Washington Hotel, Bretton Woods, New Hampshire, September 20—23, 1953. Eighty-five persons representing 16 states and 3 Canadian provinces were registered at fishery sessions. This relative low attendance was attributed to the fact that the Annual Meeting of the American Fisheries Society was held in Milwaukee a few days prior to the New Hampshire meeting. Several individuals were able to attend the divisional meeting by air travel from Milwaukee. The elimination of such conflicting dates was discussed at the business meeting and it was decided to hold the Northeastern Division meeting in the spring of the year.

Highlight of the meeting was a field demonstration by the New Hampshire Fish and Game Department of the reclamation of a 15-acre lake for trout. A panel discussion on reclamation followed. In addition to the presentation of a number of interesting papers, provision was made for all-day field trips in the vicinity of Mount Washington.

The next meeting of the Division will be held in Atlantic City, New Jersey, March 23—25, 1955. Officers for the 1955 meeting are: Chairman, A. H. Underhill, New Jersey; Vice-Chairman, Morden W. Smith, New Brunswick; Secretary, John Greeley, New York.

REPORT OF THE CHAIRMAN OF THE SOUTHERN DIVISION

JOHN F. DEQUINE

The Southern Division was formerly organized and held its first official meeting October 20-22, 1952, at the General Oglethorpe Hotel at Savannah, Georgia, in conjunction with meetings of the Southeastern Association of Game, Fish and Conservation Commissioners and the Southeastern division of the Wildlife Society. Some forty members of the Society were present, and a number of new memberships were obtained. Every state in the Southern Division was represented by one or more members.

The session was opened by John F. Dequine, Acting Chairman, and J. H. Cornell was appointed Acting Secretary. In order to formalize the actions of the meeting, the assembly unanimously voted to make the election of officers the first order of business, and the following officers were nominated from the floor and elected unanimously: John F. Dequine, Florida, Chairman; Edward Hueske, Georgia, Vice-Chairman; J. H. Cornell, North Carolina, Secretary. Appointment of sessional committees followed. The Southern Division was honored by the presence of Dr. Ralph Hile, Society President, who spoke briefly on the place of the regional divisions in the Society's activities, and advised on the procedural conduct of the meeting.

Informal papers were given, and some lively discussions were held on fish management problems and preliminary results of fisheries research in the southern United States. Creel census techniques, aquatic weed control, and freshwater commercial fisheries received most of the attention. An interesting joint session on the subject of lake and reservoir pre-impoundment clearing was held with the Southeastern Section of the Wildlife Society. Resolutions concerning the conduct of future meetings were adopted, calling for the continuance of informal sessions emphasizing panel and group discussions rather than the presentation of formal papers, and for joint sessions with the Southeastern Section of the Wildlife Society. A one dollar registration fee was approved by the membership to provide funds for the function of the Division.

The 1953 annual meeting will be held at the Hotel Patten in Chattanooga, Tennessee, October 12-14, and an attendance of more than 60 members is anticipated. An excellent program, including field demonstrations of some electrical shocking devices, has been planned by Glenn Gentry, Tennessee, the 1953 program chairman.

REPORT OF THE CHAIRMAN OF THE WESTERN DIVISION

A. F. C. GREENE

The fifth annual meeting of the Western Division was held at Long Beach, California, on June 1, 2 and 3, 1953, in conjunction with the Western Association of Game, Fish, and Conservation Commissioners.

A very successful meeting can be reported with approximately 70 people in attendance at every session. The success of the meeting can be attributed to the interesting and lively discussions and the efforts of our past Chairman, Clarence Pautzke.

It has been our experience that the symposium type discussions have proved most successful at our meetings with more time being given to discussion from the floor and less to the actual presentation of the papers. A greater interest and attendance of commercial fisheries people of the West Coast was evident and we are hopeful that they will be able to be in even greater attendance at subsequent meetings.

Officers elected for the coming year include: Chairman, A. F. C. Greene, Wyoming; Vice-Chairman, Alex J. Calhoun, California; and Secretary-Treasurer, Lewis R. Garlick, Fish and Wildlife Service, Portland, Oregon.

PRESENTATION OF SPECIAL AWARD

W. T. CALHOUN

For several years the National Association of Conservation Education and Publicity has annually appointed an award committee to select the book or books contributing most to conservation and conservation education.

That committee, in recognition of a great need for material on the elementary level, has selected for its national award the series of books comprising the *True to Life Stories on Wildlife*. These stories were written with technical accuracy, cleverness, simplicity, and an understanding of wildlife and its management.

In behalf of the National Association of Conservation Education and Publicity it is my privilege and pleasure to present its National Book Awards Certificate to Dr. R. W. Eschmeyer for his splendid *True to Life Stories on Wildlife*.

REPORT OF STANDING COMMITTEES

COMMITTEE ON INTERNATIONAL RELATIONS

WILLIAM C. HERRINGTON

In the 1951 report of this Committee it was remarked that in recent years reports have been "virtually a summary of those international negotiations with which the members may have had immediate contact." This is compared to the original purpose of the Committee "to exchange ideas pertaining to the various phases of fisheries administration, biology including fish culture, with foreign biologists, conservation and fisheries administration officials, fish culturists or agricultural societies." It was noted that "lately the task has become more and more difficult and in the not-too-distant future will be almost impossible." This 1951 Report then proposed that the incoming executive review the duties and responsibilities with a view to determining whether more specific directions might be laid down. Lacking such direction the Report continued the recent practice of reviewing and recording as many as possible of the international activities in the fisheries field during 1950.

Your present Chairman is inclined to agree with the 1951 position. It seems that the exchange of ideas pertaining to various phases of fisheries administration, biology, etc., might better be accomplished through papers published in the *TRANSACTIONS*, than by an attempt to encompass all of this in any committee report. Furthermore, the absence of any action by the Executive in response to the 1951 proposal indicates either that the Executive never got around to reading the report or that he agreed with the recent trend of this Committee's reporting.

Although I might have some personal doubts, protocol forbids me from officially entertaining the suspicion that the Executive was derelict in his duties to the extent of failing to read a Committee Report. Consequently, it must be assumed that the absence of further direction indicates approval of the recent trend of reporting. This trend therefore is continued in the present report.

This report has been assembled through the assistance of the members of the Committee and of other cooperative individuals in a position to comment on passing international events in the field of fisheries. Dr. Stillman Wright particularly contributed to the section on Technical Cooperation. However, any speculations on trends or general issues which the report contains, should be charged against no one except the Chairman.

GENERALITIES

For many years fisheries problems have provided a potent source of argument and dispute between nations. This continues to be true. If anything the problems involved become more numerous as nations extend the

range of their fishing operations. Such operations raise questions by reason both of the presence of foreign flag vessels off the coast of another nation and of the real or implied threat which such operations pose to the continued high productivity of the fish stocks. One of the most effective methods for eliminating or reducing such areas of dispute is through fact-finding by means of research performed on a cooperative basis to ensure that the results are equally acceptable to all parties.

The United States and Canada have been particularly successful in developing means of solving their fishery problems in this way—first through bilateral research and management Commissions—the International Pacific Halibut Commission and the International Pacific Salmon Fisheries Commission—and more recently through multilateral Commissions such as the Northwest Atlantic Fisheries Commission and the North Pacific Fisheries Commission. In each case, the increasing seriousness of the problem of maintaining the productivity of the aquatic resources led to a convention providing for cooperation in the study of stocks of fish of common concern and when necessary in the regulation of these fisheries.

Similar fisheries problems have in other instances led countries to unilateral attempts to extend their jurisdiction over high seas areas as a means of solving the implied threat to the productivity of stocks of fish off their coasts. Thirty years ago there was rather complete agreement among nations that territorial jurisdiction should be restricted to a band of water of three miles, or in some cases a little more, along their coasts. Since then, however, and particularly since 1945, there has been a veritable rash of claims to varying breadths of the high seas extending outward as far as the edge of the continental shelf, to 200 miles, and in a few cases to even greater distances. In most cases the most obvious stimulus for such claims has been the urge to seek sovereignty over the marine resources of the waters in the area, although other factors played their part. The usual justification has been that such jurisdiction was necessary to protect the resources from depletion or extermination by foreign fishing boats. Actually such a threat does not now exist except in a few instances, for in most of the areas in question the fisheries still are relatively undeveloped. In those cases where fishery operations have increased to the intensity where depletion threatens, experience indicates the problem can be solved through international cooperation in research and regulation. If more facts concerning the biology of the fish and condition of the stocks were available and understood by the various parties concerned, national differences would be much reduced. This highlights the importance of encouraging agreement for joint or cooperative research in areas where such problems exist, as a means of minimizing the disputes and differences which complicate our international relations.

Perhaps the general status of fishery relations in the Americas can best be surveyed by starting with the North Pacific, the center of tremendously valuable fisheries where international cooperation is most advanced, and progressing counter-clockwise about the continent.

NORTH PACIFIC FISHING DEVELOPMENTS

During 1953 the first post-war Japanese crab fishing expedition operated in the Bering Sea. This is an area of potential friction, since the most productive crab fishing grounds are rather limited in area and both United States and Japanese fishermen operated in the Bering Sea this year. There was an exchange of notes between governments and arrangements made to exchange biologists between the two crab fishing fleets to begin a cooperative program of crab research. This was preliminary to the research work which is expected to be inaugurated next year under the North Pacific Fisheries Convention. The Japanese again sent several salmon fishing expeditions to operate in the area west of 175° W. longitude. These operations were in accord with the agreement reached in the North Pacific Fisheries Convention, even though that Convention was not yet operating.

The North Pacific Fisheries Convention between the United States, Canada, and Japan, was signed in 1952 and ratifications were exchanged by the three countries on June 12, 1953. It is expected that the first meeting of this Commission will be held in the late fall of 1953.

INTERNATIONAL PACIFIC HALIBUT CONVENTION

In 1952 the International Fisheries Commission completed its twenty-first year of regulation of the Pacific halibut fishery. Prior to 1932, regulation was limited to a statutory closure of three months as described by the 1923 treaty.

In 1952 there was a notable rise in the abundance of stocks that continued the increase that has been underway since the beginning of regulation. The total yield has also increased steadily since 1930 to over 62 million pounds, the catch level in 1915.

The increased abundance under regulation coupled with greatly augmented fleets have reduced the length of the season in spite of the greater annual yield. This situation has concentrated fishing upon certain grounds and certain stocks and has not been conducive to securing the maximum yield from the grounds as a whole.

In 1951 two small underfished sections of one large area were established as independent areas and opened to fishing for a short fixed period at the season when records from earlier years showed they yielded their best fishing. They produced about 3.5 million pounds, a net gain of 2.5 million pounds over the catches from the same areas during the regular fishing season in recent years. The experiment was repeated in those two areas in 1952 with about the same net gain in yield and the method was extended to the little-fished most westerly section of the commercial distribution of the halibut, including that in the Bering Sea.

As a result of other changes in regulations, a net gain in yield of about 0.75 million pounds was taken from far westerly grounds south of the

Alaska Peninsula and Aleutian Islands and about 0.25 million was taken from the Bering Sea.

The original halibut convention, signed in 1923, was revised in 1930 and again in 1937 to enable the Commission to operate most efficiently in line with accumulating information and developments in the fishery. In the last few years it has become apparent that further modifications were needed to again bring the Convention up to date. A new Convention, therefore, was negotiated between the two Governments and signed on the 2nd of March 1953. It was ratified by Canada on May 14, and by the United States on August 18.

There are four substantive changes in the 1953 Convention: One gives the Commission authority to regulate fishing, making use of more than one open season each year. The 1937 Convention provided for only one open season annually. This change will make possible more efficient and complete utilization of the stocks and is expected to increase the annual yield at least 5 million pounds. The second gives the Commission authority to regulate the taking of halibut caught incidentally to the catch of other species, during the open as well as the closed season. The third increases the number of Commissioners from each country to three. This makes possible better representation of the area covered. The fourth changes the name of the Commission from "International Fisheries Commission" to "International Pacific Halibut Commission" to distinguish this Commission from our other international fisheries commission. Operations of the Commission during 1954 will be under the new Convention.

INTERNATIONAL PACIFIC SALMON FISHERIES CONVENTION

During 1953 the International Pacific Salmon Fisheries Commission continued progress toward rehabilitation and increase of the Fraser River sockeye fishery. Improved access to the spawning areas and increases in escapement, resulting from the Commission's work and carefully planned regulations, have resulted in continued increases in production with 1952 supplying the largest catch of any cycle-year since 1912. The escapement of all races was adequate and showed an improvement over previous cycle-years. According to present indications the 1953 run will show equally spectacular gains.

The fishery is administered so as to provide the closest practical approximation to an equal division of the catch between Canada and the United States, in accordance with the terms of the treaty. The results of the past seven years of regulation have come very close to this with 49.1 percent taken by United States fishermen and 50.9 percent by Canadians.

Increasing industrial development on the Fraser River watershed is creating numerous new hazards to full restoration of the Fraser sockeye salmon. The Commission has been able in numerous instances to make recommendations to the sponsoring governments that have resulted in adequate protection of the fisheries resource without hindering industrial development.

FUR SEAL RESEARCH—UNITED STATES, CANADA, AND JAPAN

In late 1951, the United States proposed to the four countries signatory to the old 1911 Fur Seal Convention, that the Governments undertake a joint program of investigation into the distribution, migration, and feeding habits of the fur seals of the North Pacific Ocean. In making this proposal, the United States had been guided by the fact that since the termination of World War II, Canada, Japan, the United States, and the U.S.S.R., had all indicated their interest in concluding a new convention for the protection of fur seals to replace the 1911 Convention abrogated in 1941 by Japan. A more complete knowledge of the habits of the fur seals, particularly concerning food habits, appeared to be essential to the development of a satisfactory new Convention.

Canada and Japan accepted the United States proposal, and in February 1952 parallel investigations were begun off the coast of Japan and of the North American continent, to develop information with respect to the number of Pribilof seals inhabiting those waters and feeding habits of the animals, with special reference to the species and quantities of fish eaten. Field work, which involved scientists from the three countries and some ten vessels, was concluded in July 1952. Some 3,000 seals had been taken at sea for study. Scientists from the three countries are presently engaged in the preparation of a joint report. It is hoped that the report will be submitted to the Government by the end of this year.

CENTRAL AND SOUTH PACIFIC

The United States and several Latin American countries, have mutual interests and, to a greater or lesser extent, problems, in areas extending along the Pacific Coast of Mexico south to Peru, primarily because of the operations in this area of the United States tuna fleet. The bait boats which account for a large part of United States tuna production are dependent in their operations upon obtaining supplies of live bait which are found only in the shallow waters close to the coasts of the countries in this area. The American purse seine fleet also finds it advantageous to be able to operate in the coastal waters of some of the countries along this stretch of coast. The operations of the fleet in territorial waters are carried on in accordance with licensing and other arrangements worked out with the Governments of the respective countries or in some cases with local authorities where the countries have no general legislation covering such operations. Although relations in general have been excellent, problems occasionally arise as a result of legislation designed to exclude operations of the fleet. Such legislation often is inspired by apprehension on the part of the local government that its resources are being overexploited, or a desire to provide for the exclusive exploitation of the fish stocks by its own citizens, either currently or at some hoped-for future date. Difficulties also have developed when a country charged fees for licenses which the tuna boats considered they were unable to meet because of their operating costs and competitive position, and when a country claimed jurisdiction over

wide areas of the high seas which was not recognized by the United States Government and consequently by United States fishermen.

In most cases it has been felt in the American industry that the fears of overfishing are unwarranted. In order to obtain more information on this score, cooperation in research on tuna and bait stocks has been strongly advocated. For this purpose the United States and Costa Rica negotiated the Inter-American Tropical Tuna Convention. The highlights of this Commission's operation during the past year were as follows:

Inter-American Tropical Tuna Commission:—This Commission, the first of the research and conservation commissions operating in southern waters, now has completed its third year. In spite of very severe limitations on funds needed to study the tunas and bait fish in an area some 3,000 by 300 miles plus in extent, the Commission staff has made encouraging progress on its program. The principal lines of research during the past year have been:

Collection and analysis of log book records on tuna fishing for current and past years to determine catch, relative abundance and distribution of tunas; and mathematical investigation of the dynamics of commercial marine fisheries to provide a sound basis for interpretation of the catch data.

Similar studies of the bait fish in addition to work on races, growth, and spawning.

Preliminary investigation of the oceanography of the Eastern Pacific and of the seasonal cycle of ecological changes in the Gulf of Nicoya, Costa Rica.

The new fiscal year 1953-54 began auspiciously for the Commission with the approval by the United States Congress of a considerable increase in funds for the Commission and with action by Panama to adhere to the Convention.

ECUADOR

In 1952 the Government of Ecuador seized several American tuna boats under charges of violating Ecuador's territorial waters. These seizures were discussed at a conference held in Quito between delegations from Ecuador and the United States. The conference was devoted to discussion of causes of friction and of various measures which would promote the interests of the two countries and minimize the difficulties which had developed during the past several years. The Conference made specific recommendations to the two Governments which they now have under consideration. It is expected that these recommendations may presently lead to further discussions for the purpose of developing a formal agreement designed to resolve the difficulties between the two countries.

GULF OF MEXICO

The fisheries in this area have provided an intermittent cause of friction involving Mexico and the United States, and to a lesser extent Cuba, for some years past. Fishermen from the Gulf coast of the United States

carry on shrimping operations off the coast of Mexico extending from the Texas border south to the high seas off Honduras. Cuban boats operate to a lesser extent off the coast of Mexico in the Campeche area.

The nature of fishermen (one might add—and other men) which impels them to fish where the yields are greatest, the conflicting claims of Mexico and the United States with respect to the breadth of territorial waters, and the limited policing¹ of the area, have led to repeated incidents and conflicting charges and counter-charges. American shrimp boats were seized on several occasions during the past year by Mexican authorities on charges of violating Mexican fishing laws. There have been extensive discussions of the problem among representatives of the American shrimp fishing industry and between such groups and representatives of the Mexican industry. It is expected that these discussions may presently lead to a conference between representatives of the two Governments to discuss the desirability of an agreement to cooperate in the study of the shrimp resources, and to consider other measures which might minimize sources of friction.

NORTHWEST ATLANTIC

On the Northwest Atlantic fishing grounds extending from the area off Cape Cod to the west coast of Greenland, 10 nations carry on fishing operations. The greatest problem in this area has been coordination and extension of research to determine the effect of fishing on the stocks and the need of conservation measures. For the first time in history, the activities of the interested governments have been coordinated through a formal agreement, the Northwest Atlantic Fisheries Convention.

Of considerable significance to the United States and Canadian fishing industries in the Atlantic were certain actions taken by the International Commission for the Northwest Atlantic Fisheries at its Third Annual Meeting, held in New Haven, Connecticut, May 25–30, 1953. Most important of these was the adoption of a comprehensive research program for the Convention Area. The program, the first of its kind in the history of the groundfish fisheries of the northwest Atlantic, sets long range research objectives and provides means for coordinating the efforts of the ten member governments. In addition, the Commission selected Halifax, Nova Scotia, as the site of its permanent headquarters, to be established in September 1953.

With ratification of the convention by France, Italy, Portugal, and Spain during the past year, the Commission has completed its organization and is making steady progress toward its goal.

GREAT LAKES

For the past several decades many conservationists in the Great Lakes area on both sides of the border have urged a fisheries convention to provide for cooperation of the two countries in research in the fisheries

¹ Another factor tempting human nature. How many of you hold to the speed limit on an open highway under good conditions, if you are "almost" certain that no speed cop is around?

problems of the five Great Lakes. There have also been many people who strongly opposed such a convention, or at least opposed any provision that the proposed international commission should have authority to regulate the fisheries. A convention providing for both research and regulation was negotiated between the two countries in 1946, but never was ratified because of strong opposition to the Convention, particularly to the regulatory features.

With the establishment of the sea lamprey in the four western Lakes in recent years, and the devastating inroads which it has made on the stocks of lake trout and to a lesser extent white fish, in Lakes Huron, Michigan, and recently Superior, there has been renewed pressure to negotiate a convention providing for research on and control of lampreys in addition to research on other fish problems in the Lakes. After extensive discussions between representatives of the Departments of State and the Interior, and representatives of the Great Lakes States, recreational fishermen, and the commercial fishing industry, the United States proposed further meetings with Canada to discuss the subject. Two conferences were held in an attempt to work out an agreement. The United States sought agreement on a convention providing for a commission which would carry on research and control of lampreys in all five Lakes and coordinate general fishery research on Lakes Ontario, Huron, Michigan and Superior. It would have authority to make recommendations but not to regulate. Lake Erie was not included in the general research provisions because of the strong opposition of most Ohio interests, which accounts for about 85 percent of United States production from Lake Erie. Canada was interested primarily in a general research program for all five Lakes, and was concerned to a lesser degree with the problem of lamprey control.

Complete agreement was not reached and no convention was signed or proposed for signing. However, following the second conference, the Canadian Government decided to undertake a much more vigorous program of research on the Lakes, particularly on the lamprey and methods for its control. If Canada becomes convinced that the lamprey is the primary cause of the drastic decline of Lake trout in Lake Huron and the beginning of decline in Lake Superior and that adequate control is practical, it is likely that agreement will be reached on a convention including its study and control. Success of any control program will require continuity and coordination on both sides of the Lakes, which can be ensured only by formal agreement. Whether agreement can be reached on general fisheries research remains to be seen.

INTERNATIONAL WHALING COMMISSION

The United States and Canada are concerned with one aquatic convention which does not fall under any of the preceding geographical areas, that is, the International Whaling Commission. This Commission held its Fifth Annual Meeting in London, June 22-26, 1953. Perhaps the most important result of the meeting was the amendment of the Schedule to

the Whaling Convention of 1946 to give added protection to blue whales. At its Fourth Annual Meeting, the Commission had appointed a special committee to study the blue whale populations in the Antarctic and to recommend measures for insuring their protection. At the Fifth Meeting, the special committee recommended (1) closure of the area south of 40° south latitude from the meridian of Greenwich to 70° west longitude to pelagic operations for blue whales, (2) postponing the opening of the blue whale season in the Antarctic from January 2 to January 15, and (3) reduction of the 16,000 blue whale unit limit upon the annual catch in the Antarctic. The Commission endorsed the principle of the first recommendation but decided to postpone action on it; accepted the second recommendation, substituting January 16 for January 15; and reduced the annual catch limit to 15,500 blue whale units. It is hoped that these amendments will slow and possibly halt the alarming decline in blue whale stocks which has been evident since World War II. The Commission also appointed a new committee of scientists to keep this and other whaling problems under study and report at the next meeting in Tokyo, July 1954.

INTERNATIONAL TECHNICAL COOPERATION

In recent years a new phase of international relations has developed, involving the North American countries and a number of other nations of the world. This is in the field of technical cooperation and is resulting in the extensive exchange of ideas and introduction of many new methods and techniques, particularly in a number of countries with pressing food requirements and with fishery resources which are not being fully utilized. It seems reasonably certain that through these programs the great disparity in technical advancement in fisheries in the several countries will be reduced with possible effects on their economic and political relations.

In many of the countries of the world with underdeveloped fisheries, food of animal origin is inadequate to meet the dietary needs of the people. Food from the sea is particularly important because it supplies deficiencies in protein, vitamins, and minerals. In such countries it is usually possible to augment the food supplies in important amounts by introducing improved methods of capture, preservation, transport, and marketing of aquatic resources. Low-cost preservation, transportation, and marketing are particularly important for those portions of the population which are most in need of animal proteins—usually those most remote from the coast and least able to pay high prices. The needs of the interior areas can sometimes be met in part by development of the natural fisheries of lakes and streams, and by the culture of fish in ponds, thus reducing the problems of preservation and transportation.

The character of the projects differs considerably in the several countries, but in general, activities are directed toward improvement of the diet of the people by proper exploitation and development of the fishery resources for domestic use. Problems of conservation of the fishery resources are seldom urgent, for with few exceptions the fishery resources

are underutilized. The fishery technicians, as advisers to the foreign governments frequently are called upon to aid in reorganizing or establishing government agencies for administration of the fisheries and for continuing the work of development.

UNITED STATES

For some time prior to August 1, 1953, United States programs of technical and material aid for economic development were carried out under the administration of the Director for Mutual Security by the Technical Cooperation Administration (TCA), the Institute for Inter-American Affairs (IAA), and the Mutual Security Agency (MSA). Aid to countries in Latin America was administered by IAA; to countries of Africa, the Near East, and to most countries of the Far East by TCA; to Europe and some countries of the Far East by MSA. The Fish and Wildlife Service cooperated closely with TCA and IAA in carrying out foreign fishery programs, and all fishery technicians for these programs were recruited by the Service. The Mutual Security Agency carried out fishery programs independently, except for some assistance by the Service in the training of technicians from Thailand. On June 1, 1953, President Eisenhower issued *Reorganization Plan No. 7 of 1953*, which established (effective August 1, 1953) the Foreign Operation Administration, headed by a Director, to administer all foreign aid programs of the United States (see Federal Register Vol. 18, No. 151, pp. 4541-4542). The plan provides for reorganization of the agencies concerned, but at the time of writing (August 20), they were operating without great change. The incumbent Director is Harold E. Stassen.

PROGRAMS UNDER TCA AND IAA

Fishery Mission to Mexico:—The shrimp fishery on the Pacific coast of Mexico has suffered an alarming decline in the past two years, and the oyster resources have been reduced at a time of increasing demand. At the close of 1952, plans had been developed for an expanded program of technical assistance, including low-cost preservation of marine products, conservation of shrimp resources, and development of the oyster industry, but circumstances have prevented full implementation of the program. In August, a field party for investigation of the shrimp resources of the Gulf of California entered the field under the direction of Milton J. Lindner, Chief of the Mission. It is expected that other items in the planned program will be activated in the near future.

Fishery Mission to Peru:—Further progress was made in attaining the objectives of the mission during the past year, under the direction of Robert O. Smith. During a period of six months, Norman D. Jarvis, Fishery Products Technologist, continued his program of instruction of Peruvian technicians in methods of inspection of fishery products, processing, and plant sanitation. For the second consecutive year, unusual conditions in the sea have resulted in greatly reduced catches of fish off the

coast of Peru. Accordingly, experiments in low-cost preservation of fish and full use of the fish terminal in Lima have been hampered, but it is hoped that conditions will return to normal during the next season. Charles B. Wade, Marine Biologist, who was attached to the mission for 20 months, was transferred to El Salvador in January 1953. A vessel designed for exploratory fishing is in process of construction, and it is hoped will be available for fishing in 1954. In early 1953, Mr. Smith made a survey of the fishery situation in Colombia, and prepared a plan for development of the Colombian fisheries.

Fishery Mission to El Salvador:—This mission was established in 1951 under the direction of Leroy S. Christey; and in early 1953, Charles B. Wade, Marine Biologist, was added to the staff. A trawler was acquired in 1952, and the vessel has made a large number of exploratory sets, yielding a large total of edible fish and shrimp. Success in these explorations indicates existence of a resource large enough to justify establishment of a fishing industry, and steps are being taken to that end. There is need for simultaneous development of shore facilities to insure adequate preservation, transportation, and marketing of the products. On August 1, 1953, Mr. Christey completed his assignment in El Salvador. He will depart in October for a new assignment in Pakistan. In early 1953, he made a survey of the fishery situation in the Dominican Republic, and outlined a plan for development of a fishing industry.

Fishery Missions in Liberia:—In 1952, two separate projects were set up in Liberia, one for marine fisheries under the direction of George C. Miller, another for inland waters under the direction of J. Adger Smyth. A trawler for experimental fishing off the coast of Liberia was acquired in early 1953, and preliminary trials indicate marine resources of considerable extent. Steps are now being taken to establish integrated facilities to insure that an adequate volume of processed food from this source can be properly distributed through the country. Farm ponds are being constructed in a number of places in the interior for the raising of Tilapia. It is expected that both of these projects can be turned over to Liberian nationals during the following year. The Food and Agriculture Organization of the United Nations has two technicians in Liberia, one in production of marine fishes, another in fishery products technology.

Fishery Mission to Lebanon:—This mission was established in 1952 under the direction of Elmer Quistorff, but circumstances required termination of the project and transfer of Mr. Quistorff to Egypt. In February 1953, he made a preliminary survey of the fishery resources in Jordan. The outlook for increasing production in the Gulf of Aquaba depends upon elimination of fishing with explosives, improved bait collection, and the taking of species not now entering into the catch. There seems to be opportunity for further development of fresh-water fishing from new sources of water and by building farm ponds. The primary problem in Jordan is to increase consumption of fish presently available.

Fishery Mission to Egypt:—This project was set up in May 1953, and is still in the planning stage. It is expected that efforts will be directed

primarily toward increase and improvement of fish culture in large brackish ponds connected with the Mediterranean Sea, exploratory fishing in the Red Sea, and installation of facilities for preservation, storage, and transport at ports on the Red Sea. Cairo is already served by many retail outlets for fishery products.

Fishery Mission to Iran:—H. J. Ridlon, Fishery Products Technologist, was assigned to Iran in 1952. Attention has been given primarily to reactivation of a sardine cannery constructed in 1948 at Bandar Abbas, an important fishing center on the Gulf of Persia. Fishing operations in the Gulf are suspended during the summer months, but the cannery will be put into operation when fishing begins in autumn. An effort will be made to introduce modern facilities for capture, low-cost preservation, and transport to ensure more complete use of the resources of the Gulf.

Fishery Mission to India:—In 1952, Ole J. Heggem was assigned to India to assist in carrying out the large program of technical and material assistance in development of the fisheries of that country. Early in the program, Mr. Heggem made a world tour with a group of Indian officials for the purpose of studying marine fisheries and fishing facilities. Procurement of boats, motors, and fishing gear designed to meet the needs of various parts of the country has taken the primary attention of the group since that time. The program in India is an extensive one and will require several years for completion. The Food and Agriculture Organization of the United Nations is also providing technical assistance to the Government of India.

Fishery Mission to Indonesia:—A program of technical and material assistance to Indonesia was initiated by the Economic Cooperation Administration (later the Mutual Security Agency) in 1951. The program under Frank E. Firth was later transferred to the Technical Cooperation Administration. On completion of Mr. Firth's assignment in 1953 the Fish and Wildlife Service assigned Edwin H. Dahlgren to take charge of the fisheries program. The assistance prior to 1953 was directed principally toward rehabilitation and modernization of the marine industry. This plan will be continued in part, and modified to include technical assistance in providing shore installations and services designed to ensure an integrated industry. Accordingly, several more U. S. technicians will be added to the staff in 1953 and 1954, and special emphasis will be placed upon the training of Indonesian technicians in the United States to provide for continuation of activities started under the United States program in Indonesia.

FOREIGN TRAINING PROGRAM

An important part of the program of technical assistance to underdeveloped countries is the training of foreign technicians in the United States. Under the direction of the Fish and Wildlife Service, qualified students, usually officers of government departments, are awarded training grants for periods of from three months to one year to obtain instruction, as well as practical field and laboratory training, in various branches of fishery science and wildlife management. The program provides a growing

group of technicians with special training for administrative and technical responsibility for projects when they return home.

Training is offered in the following fields paralleling the activities of the Fish and Wildlife Service: fish culture, freshwater fishery management; fishery biology; fishery economics, including marketing and distribution; fishery technology, including products and gear; wildlife management; and fur-resource technology. Study programs adapted to the individual needs and capacities of the trainee may be academic, in-service, field observation, or a combination of these types. A common pattern for the training of a fish marketing officer, for example, is as follows: after brief orientation and introduction to American governmental institutions in Washington, the trainee enrolls in a fishery school for an academic year, taking courses in fisheries science, technology, economics and marketing, followed by a three-month tour of fishing centers for first-hand observation of methods of processing, handling, and marketing. Students interested in research or management may remain in an academic institution for the full period, or devote a part of it to observation of field and laboratory projects. In supervising the training program, the Service has had cooperation from numerous schools, State conservation agencies, research laboratories, business organizations, and individuals. This assistance is essential for success of the program.

During the past year, 18 trainees from six countries were engaged in studies or training in the United States. The following table lists the countries, names of the trainees, field of training, and duration of the grant for those under instruction during fiscal year 1953.

<i>Country</i>	<i>Name</i>	<i>Field</i>	<i>Duration</i>
Pakistan	A. R. K. Zobairi	Fishery biology (inland)	12 months
	M. A. K. Rana	Fish culture	"
	A. G. Hussain	Fishery biology (marine)	"
	S. M. Islam	Product technology	"
	M. A. Burney	Fishery biology (marine)	"
	M. Ahmed	Fishery biology (marine)	"
	S. A. Jaleel	Technology & Economics	"
India	S. Jones	Fishery biology (general)	3 months
Thailand	C. Suvatti	Fishery biology (inland)	12 months
	C. Amatayakul	Fishery biology (inland)	"
	V. Yorsaengratana	Economics & Marketing	"
	S. Bundhukul	Economics & Marketing	"
Cuba	C. A. Rodriguez Lamar	Product technology	6 months
	B. Rabassa y Navarro	Product technology	7 months
	J. A. Ojeda Valdez	Gear technology	6 months
	J. A. Suarez Caabro	Fishery biology (marine)	12 months
Iraq	M. I. Al-Hamid	Fishery biology (inland)	12 months
South Africa	R. W. Rand	Fur-resource technology	7 months

Not included is a group of 11 from Indonesia who were recently awarded one-year grants. Five of these men arrived in Washington in August, three more and a young woman arrived in September. The remaining two are receiving six months of training in fishing methods at the

Velsen Fishery School at IJmuiden, Netherlands, will arrive in the United States next March for the remaining six months.

Programs under ECA/MSA:—At the start of the Marshall Plan in Europe the greatest need was for re-equipping the war-ravaged commercial fishing industries. There was a need for mechanical equipment for new or converted boats, fishing gear, and for shore stations and markets. There was little need, except in Greece, for technical assistance in fisheries. Except for the purely scientific aspects where there was an opportunity for collaboration between American and European scientists, no Europeans have been brought to the United States under fishery technical assistance programs. Several surveys were made in African Colonies of European countries, but no programs were developed.

For the Southeast Asia countries in which ECA/MSA has had programs, technical assistance has been far more important. Of the four countries in this area in which MSA has operated there have been fishery programs in Thailand, Formosa, and Indo-China. Assistance has been in the form of experimental fishing boats, nets and gear, refrigeration equipment for shore facilities and technical assistance. One special program for Thailand covered engineering services to develop plans and specifications for a badly needed modern type seafood market including a small hold-over cold storage plant.

In each of the three Southeastern Asia countries there has been an MSA fisheries specialist to provide guidance in sea fishery activities and in improving local marketing. In Thailand the MSA provided some equipment needed to implement an FAO fresh and brackish water fish program. Technical assistance training has been provided in the scientific fields and in fresh water or pond fishery activities for a number of specialists from these countries.

CANADA

Canada is participating in the technical assistance program of the British Commonwealth Nations, through contributions by the Technical Assistance Group of Trade and Commerce to the Colombo Plan in Ceylon. For the current year assistance in the field of fisheries was as follows:

A biologist was sent to Ceylon to assist in a survey of the fishery resource of the surrounding waters. An engineer was sent to assist in developing the fishery industry through advice on technical problems connected with catching, processing, storing, and transporting fishery products. Three fishery vessels were supplied. This included two 44-foot West Coast powered vessels with equipment, captain, and engineer, and a 130-foot reconverted steam trawler gear and crew.

Plans and specifications are presently being prepared for a fish processing and cold storage plant for erection at Colombo.

COMMITTEE ON NATIONAL-STATE RELATIONS

JOHN S. GOTTSCHALK

Your Committee on National-State Relations has not attempted to duplicate the comprehensive survey of cooperative programs of the agencies of the State and Federal Governments presented by the Committee a year ago. We have attempted to be on the alert for indications of change, whether for better or for worse, and our report consists of a concise review of those matters of current interest which appear to be of greatest significance.

It is a pleasure to report that we have detected no evidence of deterioration, and that it is apparent that relations between the States and the Federal Government are steadily improving. We contemplate a continuation of this harmonious atmosphere as long as there is mutual recognition and understanding of the problems and functions of the respective levels of administration of the fisheries resource. It is extremely gratifying to be able to reach these salutary conclusions.

The challenge implicit in our rapidly expanding human populations and the concomitant pressures upon our fish resources will require maximum coordination of all fisheries programs and sound cooperative effort, if we are to succeed in perpetuating and developing our aquatic wealth.

Various factors may be cited for the parts they have played in bringing our relations to their present levels. The establishment of Federal-State cooperative programs, which require close and frequent contact between responsible officials, automatically stimulates better understanding between State and National governmental units. The newest of such programs is the Federal Aid in Fish Restoration Program. Now well started in its third year, it is furnishing a new stimulus and badly-needed financial assistance to sport fish management programs.

The Fish and Wildlife Service reports that \$3,160,045.13 was obligated in 261 Federal Aid in Fish Restoration projects during the year ended June 30, 1953. Of these, 121 were designed to support scientific investigations of various fisheries problems; 40 will provide for the improvement of the aquatic habitat; 53 involve the purchase or lease of lands needed in some phase of restoration work; and the remainder establish requisite supervision of Federal programs by the respective States. Notable, though anticipated, shifts in numbers of the various types of projects occurred during the year. In terms of percent of total funds obligated, investigational work dropped from 63 to 46; development and land purchase activities rose from 24 to 40, and 3 to 8, respectively; and coordination dropped from 10 to 6 percent. Prospects for broadening the benefits from this program brightened materially with an increase in revenue of 72 percent over the previous year. The apportionment of funds to the States and Territories for the current fiscal year totalled \$4,319,916 out of total receipts of \$4,556,615. Every State in the Nation, and each of the eligible Territories, is now participating in the program. An indication of program progress may be gained from the knowledge that, at the end of

the two-year period of availability of first year funds, only \$4,739 reverted through lack of obligation, to the Fish and Wildlife Service. This money is allotted to the sport fish research program of the Service. The first reverted funds will be used to support investigations of the Atlantic salmon.

The bulk of the Dingell-Johnson projects deal with the problems of sport fishing in our fresh waters, and are patterned along traditional lines. There is, however, a growing interest in and recognition of the recreational potential of the marine sport fishes of our coastal waters. At present, 9 States and Territories are conducting 13 projects dealing primarily with the restoration of marine or anadromous fishes. Of particular interest among projects concerned with marine species is one which has been established by Maryland for the study of factors affecting the spawning of striped bass in the Chesapeake Bay. It is the first step toward a cooperative investigation of the striped bass. The over-all study is sponsored by the Atlantic States Marine Fisheries Commission, with coordination provided by the Fish and Wildlife Service and the actual investigations conducted by the individual States on the Atlantic seaboard.

As a direct aid and stimulus to improved cooperation among project workers, the Fish and Wildlife Service began publication of the Dingell-Johnson Quarterly, and issued Circular No. 21 entitled *Survey of Fisheries Activities*, 1953. The former reports progress and accomplishments registered under the Federal Aid program. The latter represents a listing of current sport fish research and management currently in progress in the United States. At the Dallas meeting, the Society officially urged that a survey be conducted, and the Society can take credit for the unification of interest which resulted in the publication of the survey results.

Although your Committee makes no claim to unusual psychic powers, it would seem that the most significant single event which will affect the course of Federal-State relations in the next few years occurred on January 20, 1953. Among the many changes which will result from the appearance on the Washington scene of a new team of managers for the Federal estate, one clear-cut trend stands out. This is an avowed and demonstrated intention to foster a greater recognition of the sovereignty of the individual States. As yet, it is not certain what effect this attitude will have when applied to fishery matters. Subsequent committees may have more to report on this subject.

The conflict between fisheries interests and those which have favored the wholesale development of our water resources for varied purposes, has frequently resulted in breaches in the normally good relations which have prevailed between Federal and State agencies during the past few years. No important developments have occurred in this arena during the past year. The western States are continuing their struggle to obtain assurance of adequate consideration of the fishery resource as an integral part of the early planning for water control structures. The important court cases involving the proposals for the construction of dams on the Cowlitz River in Washington have not yet been decided. Wisconsin's fight to prevent the

construction of dams on certain streams judged to be of special scenic or recreational value, suffered a reversal through the failure of the State legislature to pass Senate Bill 11B. This proposed legislation would have established the authority of the Conservation Commission to designate in a priority listing those streams on which dams would have been prohibited. Throughout the country, there has been a general, albeit slow, improvement in the recognition of the States' basic responsibility for the management of all its non-migratory species of fish and wildlife. More and more State-managed wildlife and fisheries programs on Federal lands and reservoirs are being put into operation.

In the closing hours of the 83rd Congress, \$5,000,000 was appropriated for the Department of Agriculture's program of cooperative watershed development. The purpose of the authorized program, which will extend for a 5-year period, at a total cost of about 29 million dollars, is to demonstrate the practicability of complete watershed protection as a means of conserving soil and water resources and alleviating damages from floods. Known as the Andersen-Hope Watershed Protection Program, it will provide a means of developing practicable working relationships and procedures by which organized local groups, in cooperation with State and Federal agencies, can carry out their planned programs of improvements within limited periods of time. It is anticipated that State conservation agencies may enter into the cooperative realm of his program in a number of ways. A few States may take an active participation as cooperators, while others may find it desirable to organize studies of the effect of the watershed treatment programs to show the relationship of the planned work to stream fish resources.

In another action, Congress made heavy reductions in the appropriations for water pollution control activities. This work, which was authorized by the Taft-Barkley Law of 1948, provides for Federal assistance to the States in pollution control and needed investigations. As a result of the limited appropriations, field work of the Water Pollution Division of the Public Health Service, has been substantially curtailed for the current fiscal year, and research grants have been eliminated for the second successive year.

In addition to the actions on appropriations, a number of other Bills were introduced in the 83rd Congress which would affect the conservation of the fishery resources in various ways. H. R. 4585, and an identical companion Bill, H. R. 4787, would make the striped bass exclusively a game fish in all maritime and territorial waters under U. S. jurisdiction. The Society, in past years, has condemned similar legislation on the basis that it does not provide for a realistic approach towards the management of this important coastal species, since no provision is made for the studies needed to determine the effect of commercial or sport fishing on the available stocks of striped bass; also, the proposed legislation was construed to be a negation of State sovereignty in a field which has historically been subject to State authority. The new legislation largely takes care of the latter objections, but there remains the questionable pro-

cedure which gives predominance to political considerations rather than the factual aspects of the case. At the time of the adjournment of Congress, the Bill had not been reported out of Committee. Incidentally, during the last session of the New Jersey legislature a Bill which prohibits the capture of striped bass with nets was enacted into law.

No other legislation directly affecting the fisheries was introduced. Several pieces of legislation of interest to fisheries workers because of the relationship between their subject matter and fish conservation, were introduced. The Baker Bill, H. R. 1972, which provides for earmarking 10 percent of National Forest revenues for the support of recreation and wildlife improvements on the National Forests; and the Hope Bill, H. R. 4268, establishing National Forest multiple use advisory councils, were both generally favored by conservation interests, but did not reach a vote on the floor of the House of Representatives. Conservation interests joined forces in opposition to two other Bills. The D'Ewart Bill, H. R. 4023, which was the so-called Stockmen's Grazing Bill, and the Ellsworth Bill, H. R. 4646, which would permit dam building agencies to acquire land for reservoir purposes through exchange of National Forest land, both remained in Committee. What was viewed as a potential threat to America's conservation effort failed to gain headway in this Congress, due to the concerted efforts of conservation interests.

The Committee Chairman wishes to express his appreciation for the counsel and assistance of the Committee members.

EDITORIAL BOARD

KIYOSHI G. FUKANO

Volume 82 of the *TRANSACTIONS* of the Society was mailed to the members early this month. This volume is the first in 10 years to be published in advance of the following meeting. Distribution on schedule was possible through the hard work of the Associate Editors and the assistance of Ralph Hile. Volume 82 is the real Report of the Editorial Board.

Since the last meeting the Board has received 10 papers for possible publication in the next volume. Some of these papers are now ready for the printer. Our goal is to have the *TRANSACTIONS* in the hands of the members as early as possible in 1954.

COMMITTEE ON HYDROBIOLOGY AND FISH CULTURE

A. V. TUNISON

Appraisals of fishery research and management have been presented to this Society on numerous occasions. Although this Committee may be subjected to criticism for being repetitious, we believe that the subject is in order and a humble attempt will be made to point out some of the

voids in our present-day programs. The fate of our fisheries in the next 10, 20, and 50 years should be of major concern. Too often we, like the generations before us, are too concerned with current problems to spend much time in planning for future generations. Planning for the future is a part of many agency programs, but its design and scope are often a protraction of current programs with little regard to the potential effects of changing world conditions.

Twenty years ago about 4 percent of the people in the continental United States bought fishing licenses, in 1940 about 6 percent bought fishing licenses, and in 1950 the percentage of purchasers had increased to more than 10 percent. In the fiscal year 1952 the number of fishing licenses sold amounted to a little more than 17,000,000 as compared to the 4,858,000 sales 20 years before. These figures ignore the number of people who fish without a license, and the increase in licenses sold may be due, in part, to legislative action requiring licenses to fish rather than to an increase in fishermen. In view of the various factors which affect the potential number of fishermen, however, it seems reasonable to predict that the number of fishermen will more than double during the next 20 years.

The number of waters suitable for the warm-water game-fish species appears reasonably certain to increase as a result of the construction of reservoirs, fishing lakes, and farm ponds. Some commercial species likewise will benefit. Increases in our population will accentuate the demands for power, irrigation water, forest products, mining, and agricultural products. Any or all of these demands, if satisfied, will decrease the amount of suitable water available for trout and for the fresh-water life of the salmon. The development of atomic power, conversion of salt water for irrigation, and improvement in agricultural practices may help to offset a part of these demands.

Faced with the ever-increasing fishing pressure, reduced habitat for the cold-water fish species, and more warm-water habitat, what program changes should we be considering for fisheries research and management? Survival of desirable species in the various waters is very poor, particularly in the early life of the fish. On the other hand, many fish die of old age. Increasing the survival and the catch is necessary if the increasing fishing pressure is to be satisfied at its present return per unit of effort expended.

Studies on fish survival involve population counts and the productivity of the water, along with an assessment of other factors usually associated with individual species. Although the electric shocker and certain poisons have done much to improve the accuracy of population counts, we still must use a great amount of discretion in handling such data, and the need for prudence increases with the size of the body of water. It would seem apparent, then, that research to develop more accurate and efficient methods of determining fish populations should receive relatively high priority.

Usually the productivity of a body of water is measured by the harvest of fish. Basically the productivity of the water depends upon its chemical and physical composition, which produces fish food and fish if other en-

vironmental conditions are satisfactory. Too little is known of the effects of the various chemical elements on the production of aquatic fish food. Although we use qualitative expressions of fertility, we have no suitable yardstick to measure it quantitatively. One could rightfully question many of the expenditures of funds for water analyses. Of what use is the usual water analysis in improving the harvest of fish in a body of water that already contains live fish? The agronomist can predict the responses that may be expected in crops after the addition of certain chemicals. Soil deficiencies have been determined for various parts of the country. The addition of small amounts of trace elements to the deficient soil has resulted in the economical production of crops and livestock. The effect of these elements in the production of aquatic fish food and fish has barely been touched, yet in many areas the water in the streams and lakes drains from mineral-deficient soils. Basic research directed toward measuring quantitatively the relationship of the chemical and physical properties of water and the production of fish food and fish should be encouraged.

We need to know also the relative importance of other environmental factors on the production of fish food and fish. Thousands of dollars have been spent on stream improvements. Some of the improvements—made at the expense of the fisherman rather than the landowner in some instances—have been an asset as far as soil conservation is concerned. However, what quantitative measurements have been made of increased production of aquatic fish food? of fish? What is the cost-benefit ratio? Until more is known of the reasons for poor survival of stream fish, where should the emphasis be placed in stream improvement work? on food production? on protection for young fish? or, on protection for catchable-size fish?

Increasing the fish-food supply in lakes and impoundments has received attention, particularly in the development of farm ponds. The addition of fertilizer to small impoundments will improve the production of fish, other conditions being equal, and is considered economical. It is not practical to add fertilizer to large lakes or impoundments, and their fertility reflects that of the drainage basin. Although other means have been considered, apparently there is still no practical, economical solution to the problem of improving the fertility of large impoundments and lakes.

Habitat improvement in lakes and impoundments has been on a modest scope as compared to that in streams. Brush shelters were once advocated as fish protection devices but now find greater use as a means of increasing the harvest of fish that might otherwise die of old age. Specialized areas designed to improve the supply of food and young fish have been recommended for impoundments where topography permits, but their use has been limited and their benefit is questionable. The habitat in some lakes and impoundments has been affected indirectly by the chemical control of vegetation. This has been carried out primarily for the benefit of cottage and resort owners as well as boat operators. The destruction of the vegetation adds fertility to the water, aids mosquito control, destroys protection for young fish, and improves the harvest of fish. The proper methods to use for the control of all types of vegetation, however, have not yet been determined.

The habitat in some impoundments has been drastically affected by the fluctuations of the water levels resulting from flood control and hydroelectric operations. Although fluctuations might be employed at times to the advantage of fishery management, provided that we knew more of their effects, such use has been limited by the priority of the primary operations.

Another major fishery problem of impoundments, and of other waters as well, is the conflict between sport fishing and commercial fishing. These interests should complement each other if we are to get maximum fish production from the waters. Unfortunately, competition for the same species in some areas has discouraged harmony. The development of means to utilize economically the nongame or rough fish is a very urgent problem, and its solution would do much to improve the management of many impoundments and rivers. Coastal States and commercial fishing interests have encouraged and supported fishery research in the development, handling, and marketing of marine fish; but similar enthusiasm for the inland commercial fishery has been lacking.

In addition to the commercial operations, other means of controlling undesirable species in large impoundments have been tried or considered, but their use is limited. Complete or partial poisoning is expensive in big waters. Dewatering is a successful means of control in the smaller waters. Introduction of new predator species is being tried and may prove effective in some instances. The use of sterile hybrid predators is under trial but appears to require further study. Solving the problem of economically increasing the production of some species at the expense of others will require many years of research and should not be postponed. Suitable waters placed under the control of fishery interests to serve as "laboratories" would be helpful.

As far as smaller impoundments are concerned, reasonably good success with fertilized farm ponds have been achieved in the southern States. If the ponds are properly constructed, fertilized, and stocked, and if weeds are controlled, the sport fishery harvest may be good for some years. There are areas where soil types, temperatures, or other conditions cause failures even though the usual recommended procedures are followed; thus continued research is needed. If species other than the largemouth bass, bluegill, and redear combinations are desired in a pond, the chance of success is poor. In fertilized ponds in the northern States the bass-bluegill combination has been less successful; and this species combination, as well as others, needs considerably more study. The shorter growing season, slower growth and maturity, and winterkill present problems in the North. The greatest farm-pond problem today is the management of unfertilized farm ponds. Suitable species combinations, stocking rates, and other management principles have not yet been developed for this type of pond.

The bulk of the work done on farm ponds has been directed toward game species to be taken by hook-and-line fishing. If the purpose of such studies was to benefit sport fishing and relaxation, with food production a secondary consideration, the work was well directed. If the purpose of this work was food production, one might rightly question the selection of species and means of capture. There is a demand for information on

how to propagate profitably suitable species of warm-water fish for the commercial food market. Interest has been shown in catfish, buffalo, mullet, and carp. If fish production per acre in farm ponds needs to be increased for food purposes, means of harvesting other than hook-and-line fishing should be developed and legalized.

Reduction in the fresh-water habitat of the Pacific salmon threatens this resource. Solutions to the problem of maintaining the salmon fishery for commercial and sport interests are neither many nor optimistic. Available streams can be improved to permit greater spawning, but food supply and other factors may limit the survival of the increased fry production to little more than it is today—usually less than 5 percent of the potential egg deposition.

When the height of dams is not prohibitive, adult salmon migrating upstream to spawn can pass over them by means of ladders. As the number of laddered dams increases, spawning is further delayed, and some fish may fail to spawn for this reason or because of exhaustion. Backwaters above the dams reduce spawning areas. Assuming that by one means or another eggs or fish can be deposited in tributaries above the dams, the major problem is the safe passage downstream past the dams. Losses occur during passage over the dams or in the turbines. Various means—lights, electrical devices, and mechanical attractors and deflectors—have been tried in an endeavor to lead the downstream migrants to safe passages at the dams. Results are discouraging, and continued research is necessary.

The use of season and creel limits is a management tool employed to regulate the harvest of fish. Unfortunately, the laws are often statewide and fail to take into account the productivity of specific waters, thus losing their effectiveness. This deficiency is becoming recognized by the States and Provinces. The recent work on South Saskatchewan trout streams in Alberta is an example. The growth rate of trout in each stream has been determined, and on the basis of this work the streams are opened to fishing the year around—with no size limits—every 2 years where growth is rapid and every 3 years where growth is slower. It is a sound means of utilizing the productivity of the streams to the best advantage.

Great concern is often shown in designing the laws to permit the escapement of an "adequate" number of brood fish. If loss of brood fish by angling is not serious as compared to losses by natural causes, then one may question the need for some of the existing laws. If recruitment is not a problem, relaxing the size limits would increase the production per acre by permitting harvest of fish that would otherwise die of natural causes. If restrictions are to be used as a management tool, their design should be based on biological information.

Many industries and municipalities are spending considerable sums of money to eliminate pollution. Some industries have found that the salvage of pollution products will pay, at least in part, the expense of the control measures. It is believed safe to assume that industry will accelerate its pollution control programs. Likewise, it is believed that municipalities will accelerate their sewerage treatment projects, primarily for health reasons. Pollution from soil erosion (siltation) is a major problem in many areas.

Soil conservation practices have done much to prevent the loss of the farmer's soil and at the same time to improve fishing. Research on the control of pollution will be required indefinitely as new products come into manufacture and as the population grows.

Research has improved the production of hatchery fish, but there are still numerous problems. Many improvements have been made in the design of rearing facilities since the early days of fish culture, but when one examines the progress made in other types of animal husbandry, it becomes apparent that we have only begun to modernize. The designs of ponds and raceways, as well as other facilities, should be improved to effect savings in labor, one of the most expensive items of fish production. Too little attention has been given to designing and using equipment which would increase production and save labor. Present-day equipment used in distributing fish is much better than the 10-gallon milk can but still is inefficient. The recent trials with anesthetics, oxygen under pressure, and other chemicals may point the way to solving the distribution problem. If this work is successful, it may be possible to abandon the small units and concentrate operations at the larger, more efficient hatcheries.

Research is being continued on the nutritional requirements of trout and salmon. The use of fish-food pellets may revolutionize the operation of these hatcheries. Little work has been done on the nutritional requirements of the warm-water species. The study of parasites and diseases in salmon and trout continues, but only minor attention is being given to the warm-water species. Recent reports call attention to high losses caused by virus diseases in salmon and trout.

Sporadic studies have been made on fish genetics. The need for good research in this field is urgent. Perhaps the most difficult problem will be the definition of the desirable product. The greatest use of genetics in fisheries has probably been made with the ornamental species. Selective breeding may offer one solution to the problem of mass-marking hatchery fish for later creel identification—a management technique given much less study than it deserves. The States of Pennsylvania and New York—perhaps others—are conducting selective breeding studies with trout, and the results should help to reduce the cost of raising trout as well as improve their quality.

Controlled spawning of hatchery warm-water brood species to avoid loss of eggs and fry because of weather conditions is an urgent practical problem. Some hatcheries have water supplies whose temperatures naturally retard spawning. The State of Texas, and perhaps others, heats the water in the brood pond to hasten spawning, thus permitting the stocking of predator species in open waters ahead of the rough-fish spawning. Hormones have been used to hasten spawning in some species, but studies are incomplete. The crowding of brood stock retards spawning, but the method needs perfecting. Regulation of light, effective in controlling trout spawning, has not been tried for warm-water species.

Fish culture in this country began with the propagation of trout, and the problems involved therein were largely responsible for the creation of this Society. The use of the hatchery product in establishing desirable

trout populations in barren and other waters in the early years is well known. During the last several decades the use of the hatchery trout to maintain, and possibly increase, wild trout populations has been questioned—and rightly so. Studies have shown that the survival of hatchery trout, especially that of small fish used for stream stocking, is low. The causes of the mortality have not been studied sufficiently to permit the institution of corrective measures where practical and economical.

The use of catchable-size trout for put-and-take fishing has accelerated at a rapid pace in the last 10 or 15 years, and further use is limited in many States only by the lack of funds. These fish have been superimposed on wild populations in many places, and the survival has ranged from a small percentage to about 80 percent in ideal situations. North Carolina recently reported some interesting returns from legal-size trout stocking: 10 percent for fall stocking, 35 percent for pre-season, and 45 percent from trout stocked during the fishing season.

Few people have stopped to realize that the survival of catchable-size trout to the creel can range from 0 to 100 percent, laws permitting. Stocking in waters never fished would mean a total loss—and removing trout from the hatchery pond, the other extreme, would be the most economical return on the sportsman's dollar. Fisherman's Paradise in Pennsylvania approaches the latter condition. In 1952, in the 1-mile section of Spring Creek located on the property of the Bellefonte hatchery, nearly 21,000 persons fished about 44,000 days to catch and keep, in accordance with special regulations, 75 percent of the 12,000 trout stocked. It is not unlikely that projects of this type will multiply in the years to come. If economics continues to be one of the major criticisms of hatchery trout production, then one of the first steps might be the development of more areas like Fisherman's Paradise where assurance of returns is high. The second step would be the development, through breeding and feeding, of a "trout" suitable for such areas and cheap to rear. Commercial trout growers have wished for years for such a "trout" to supply the demand for table trout. Perhaps a caponized trout hybrid would be the answer. It is a good practical research project.

The foregoing is an attempt to point out some of the problems on which research is needed to improve the sport fisheries in the next several decades. Your Committee recognizes the valuable contributions that are being made by investigators in various places. Many of the 540 projects reported in the recently published *Survey of Fisheries Activities, 1953* (Circular No. 21, U. S. Fish and Wildlife Service) deal with the basic problems. Likewise, the first issue of *The Dingell-Johnson Quarterly* lists a number of projects which are delving into the unexplored areas of fish management. On the other hand, it is almost painfully obvious that much of the so-called research is not research in the classical sense and is contributing nothing original or basically significant. This may be amply illustrated by reference to the two publications just mentioned. The Committee recognizes that there are many problems requiring immediate solution by the best means available. No one argues for the elimination of this type

of work, as everyone concedes that "solutions" marked by expediency will always be with us.

Yet, we must ask ourselves if our total effort, however valuable it may be, will furnish the guidance to keep us moving straight on the dim road of the future. Is enough of our effort going into the type of research that will provide the working hypotheses of the next half century? To ask the question another way: Are we too preoccupied with day-to-day problems to give sufficient attention to our long-range needs?

Your Committee has high-lighted a number of fundamental problems which are fairly clamoring for attention. Means are available in most States to carry on the obvious projects. The Dingell-Johnson program, now beginning its third year, offers encouragement that more attention will be given to the exploration of the frontiers of fish management. This program operates on the premise that the trouble-shooting type of work will be performed with regular State funds where necessary. If our projects—whether Federal, State, institutional, or cooperative—neglect the basic research problems, the improvement of management techniques and the development of solutions to many major problems will be postponed for years to come. Now is the time to recognize that tomorrow's success in maintaining our future depends upon the foundation we build today. In fisheries, as in many other fields, that foundation must be built with more and better research.

COMMITTEE ON COMMERCIAL FISHERIES

J. L. HART

UNITED STATES AND ALASKA, 1952

Despite a record production of menhaden, the United States and Alaskan catch was one of the smallest in recent years, owing to the failure of the pilchard fishery and reduced landings of salmon and ocean perch. The total catch of 4.3 billion pounds in 1952 was valued at \$325,000,000 to the fishermen.

Menhaden, used entirely for the manufacture of fish meal and oil, yielded a catch of 1.35 billion pounds, over 30 percent of the total landings of all fish and shellfish taken by United States and Alaskan fishermen. Landings of menhaden in the relatively new Gulf of Mexico fishery were unusually large and accounted for over a third of the total yield of these fish.

The Pacific Coast pilchard, which for many years supported the nation's largest fishery, was an almost complete failure, yielding a catch of only 7,500,000 pounds. This was only one-twentieth of one percent of the record pilchard catch of 1,502,000,000 pounds made in 1936. Available information indicates that there is little prospect for the recovery of the fishery in the near future.

As a result of the failure of the pilchard fishery, extensive canning of

anchovies for export was undertaken at Monterey, California, and over 50,000,000 pounds of these fish were taken during the year. The pack of canned anchovies totalled 439,000 cases, compared with only 41,000 cases the previous year. The California industry turned its attention to jack mackerel also and the 1952-53 season promises to be the best on record.

The Pacific Coast mackerel fishery was a complete failure in 1952.

The United States and Alaskan catch of salmon remained below normal in 1952, and the catch amounted to less than 400,000,000 pounds. The pack of canned salmon, which totalled 4,464,000 cases, was, with the exception of the 1950 pack, the smallest since 1921.

The use of power-operated gill-net boats by the salmon canneries in Bristol Bay became general in 1952. The use of these craft was first permitted by the Fish and Wildlife Service in 1951. Prior to that year only sail gill-net boats were allowed in this area. The use of power opened the way for the expansion of freezer-ship operations in Bristol Bay and 18 of these craft engaged in the freezing of red salmon in 1952. This was double the number operated in the previous year. The frozen salmon were taken to Puget Sound and canned in the shore canneries in that area. Use of powered gill-net boats and of freezer ships represents a major change in the method of capturing and handling salmon from Bristol Bay.

Despite a decrease in catch of ocean perch, due to economic conditions, these fish continued to be the principal food fish taken off the Atlantic Coast of the United States. Landings of ocean perch at New England ports in 1952 totalled 189,000,000 pounds, compared with 258,300,000 pounds in the previous year. As in the past, the entire catch was marketed as fresh or frozen fillets. The catch of ocean perch, as well as that of New England groundfish, in 1952 was restricted by the record imports of groundfish, ocean perch, and other fillets, which totalled 160,600,000 pounds, compared with 133,200,000 pounds the previous year.

The market for canned tuna improved somewhat during the year and, after a slow beginning, the catch picked up and reached about 340 million pounds. This was the second largest catch in history, falling about 10 percent below the record 1950 catch of 395 million pounds. Investigations conducted in the Central Pacific during the year indicated that there exists in the region near the equator a vast population of tuna which may become one of the world's important sources of these fish. The fish appear to occur at a considerable depth and to be scattered rather than in dense schools. It therefore appears that the conventional live-bait and purse-seine methods used by United States fishermen in taking tuna would not be successful in the mid-Pacific. It is probable that long line gear will be required to utilize this tuna resource. United States fishermen do not use this type of gear in the present tuna fishery.

Supplies of albacore did not appear on Pacific Coast fishing grounds north of California. There, however, catches were good.

A fishery for shrimps off the coast of central California, pioneered in 1952 by the California Department of Fish and Game, expanded greatly, producing 205,485 pounds of ocean shrimp, 912,558 pounds of bay shrimp, and 3,016 pounds of prawns.

There is a growing conflict between sports-fishing interests and those of commercial fishermen. In Chesapeake Bay and the surrounding area the sports fishermen maintain that commercial operations have reduced the supply of fish. The Virginia State Fisheries Laboratory is concentrating considerable effort on a study of the reasons for the decline in the croaker or hardhead. In Florida a supervised seining program for sunfish was summarily stopped because of pressure by sports fishermen although the operation had produced improvements in the measured sporting catch of bass, nine million pounds of sunfish, and a profit of \$60,000 to the State. In Louisiana similar pressure led to dropping projects for harvesting the transient shrimp crop in 600-square-mile Lake Pontchartrain, although the plan had the approval of a committee of nationally known fishery scientists.

In the Great Lakes the sea lamprey situation continues to be a matter of great concern. Its prevalence is regarded as the cause of the commercial disappearance of the lake trout in Lakes Huron and Michigan. Further, little optimism is entertained for the future of the lake trout fishery in Lake Superior. Considerable research effort is being devoted to measures for controlling lamprey. Lake herring in Lake Superior and chub (deep-water ciscoes) in Lake Michigan continue to produce satisfactorily. Whitefish and blue pike production showed improvement in Lake Erie and blue pike in Lake Ontario.

Most of the states on the Atlantic Seaboard are now co-operating with the Fish and Wildlife Service in gathering up-to-date commercial catch statistics. New Jersey has inaugurated a marine sports-fisheries catch survey. New Jersey and New York have begun marine projects under the Dingle-Johnson Act and it is anticipated that these funds will accelerate marine fisheries research as soon as states with separate marine fisheries departments can work out means of sharing the funds with their freshwater counterparts.

The United States has become substantially dependent on imported fishery products. In 1952, products from more than one billion pounds of fish and shellfish were imported into this country. A catch of more than two billion pounds was required to provide nonedible products, principally fish meal, received from foreign countries. If United States fishermen had attempted to provide this additional three billion pounds of fish, it would have required an increase of over 70 percent in the domestic catch. For every 10 pounds of domestic fish caught, processed, and distributed in 1952, the equivalent of seven pounds of foreign-caught fish are also handled. It is obvious that a growing part of the United States fishing industry's processing and distributing facilities is devoted to foreign fish.

The fisheries of the Hawaiian Islands were down in volume and value. The decline was due almost entirely to the reduced catch of skipjack (Aku) which fell to 57 percent of the previous year—a good one.

CANADA, 1952

Canadian commercial fisheries annually yield about two billion pounds, worth nearly 200 million dollars. In 1952, landings amounted to about

800 million pounds in the Maritime Provinces and Quebec, 600 million in Newfoundland, and about 400 million in British Columbia. Some 100 million pounds from inland areas brought the total to about 1.9 billion pounds. The market value of the catch was estimated at 72 million dollars in the Maritimes and Quebec, 28 million in Newfoundland, 58 million in British Columbia, and 20 million in the freshwater areas, a total of 178 million dollars.

On the Atlantic Coast, the Maritime Provinces and Quebec showed a general improvement in the fishery. Landings of groundfish increased substantially with a corresponding increase in value. The increase was chiefly the result of increased fishing effort. Landings of haddock increased relatively more than for cod. Lobster landings were somewhat smaller but the excellent market for fresh lobsters was reflected in increased prices to the fishermen and the fishery was worth a million dollars more than in 1951. The upward trend in the production of Atlantic halibut seems to be reversed, and the 1952 catch of four million pounds is only about half that of the preceding year.

The sectional meeting of the International Commission for the Northwest Atlantic Fisheries adopted a minimum mesh size for trawls on an experimental basis in sub-area 5 (New England) ($4\frac{1}{2}$ inches inside measurement when in use as against the meshes of $2\frac{7}{8}$ inches or sometimes less employed previously). The effectiveness of the restriction is to be studied by comparing the relationships of relative abundances of year classes to their yields in the fishery before and after the regulation is applied.

When the 1952 season for herring sardines in the Bay of Fundy opened there was a carry-over from the previous year still unsold. Consequently the fishery got off to a slow start. Canadian plants operated well below capacity with the result that by the end of the year they had cleaned out their stocks. Some catches were sold to canneries in Maine. The total catch in 1952 was 54 million pounds, 10 million less than for the preceding year. The value dropped by more than half.

In Newfoundland, as in the other Atlantic provinces, there was an increase in capital investment and processing plants, largely in response to proved market demand for cod fillets. In Newfoundland progress has resulted from the introduction of long-lining in inshore waters and from extensive exploration. However, the scarcity of dollars in former markets of Brazil, Spain, and Portugal, etc., continued to limit the export trade in salted cod-fish. The year brought no new trends, only a continuation of the swing away from the traditional shore cure toward mass-produced fillets.

On the prairie lakes and in the Northwest Territories trouble was experienced in marketing the catch because the unusually mild winter made all customary methods of transportation difficult.

The British Columbia fisheries which had increased in value from 22 million dollars in 1941 to 86 million dollars, dropped to 58 million in 1952. Difficult marketing conditions made producers unwilling to accede to fishermen's price demands. Strikes and fishing stoppages resulted. Trawl-

net fishing was suspended from late April to late June. In July when sockeye production was at its peak in several areas, gill-net and seine fleets stopped operations for six days. Later these fleets stopped fishing again in September and October. The beginning of the whaling season was delayed by a month. There was no fall or winter herring fishery for reduction purposes. On the whole sockeye runs and landings were good and not too much affected by economic conditions and pink salmon landings were little affected. The landings of chinook and coho salmon by trollers represent the availability of the fish as there were no fishing tie-ups. Fishing effort for most other species was significantly curtailed.

Halibut was the second most valuable catch. The season was opened two weeks later than usual in an effort to spread fishing effort to relatively unexploited stocks. In an additional effort toward the same end, a special late opening was authorized on selected grounds. The international quotas were quickly filled and Canadian fishermen landed their biggest catch since 1947. They took nearly $23\frac{1}{2}$ million pounds with a landed value close to four million dollars.

In 1951 a disastrous rock-slide in the Babine River prevented access to Babine Lake of an estimated two-thirds of the sockeye salmon run. In 1952 marginal improvements along the edge of the slide were carried out during the run and the number of fish reaching the lake more than doubled although loss was still severe. The marginal improvements were more or less incidental to the survey for a complete removal of the slide. This has since been carried out with very satisfactory results.

During 1952 the use of nylon tangle nets for salmon fishing in the Fraser River became fairly common. In these nets as much as a thousand fathoms of web are hung on 200 fathoms of cork line. This gear, especially in daylight fishing in clear water, is very effective and new problems in regulation are raised.

COMMITTEE ON NAMES OF FISHES

REEVE M. BAILEY

During the past year the Committee has continued its consideration of certain proposed changes in common names and, as usual, has received and cleared inquiries pertaining to the nomenclature of fishes. Also it has advanced the formulation of a policy statement designed to serve as a guide in the selection of vernacular names. However, none of these undertakings calls for formal report to the Society at the present time.

REPORTS OF SPECIAL COMMITTEES

COMMITTEE TO STUDY PUBLICATION OF *TRANSACTIONS*

JOHN VAN OOSTEN

Pursuant to the instructions contained in the resolution adopted at the 1952 Dallas meeting establishing the above committee, we wish to report as follows.

On June 19, 1953, a letter was addressed to 15 university presses. A similar letter was forwarded at the same time to the American Institute of Biological Sciences, Washington, D. C. Personal contact was also made by the Chairman with the Editor-in-Chief of *Copeia*. Replies were received from 14 university presses and from the AIBS. Eleven of the presses and the AIBS could offer no editorial or contractual assistance but did express plenty of sympathy.

The AIBS has a committee on publications which has been studying publication and editing problems. This committee has issued a mimeographed report on establishing a business service for biological journals. This service would include such items as maintenance of mailing lists, billing members for dues and reprints, receiving moneys, keeping records, furnishing the printer with addressed wrappers or envelopes for mailing the journal, filling orders for indexes and the journal, renting storage space in Washington for back issues for no longer than 5 years, and answering routine inquiries concerning the journal. It was estimated that the cost of such service would amount to about \$1.50 per subscriber. The executive director of AIBS stated that its committee felt "that editorial services might be the next logical step in the development of such a program." If such a step is taken by the AIBS it is suggested that our Society again contact this organization and examine its new proposals for editing services. To participate in any AIBS cooperative undertaking, the Society would have to become a member or an affiliate. Cooperation with the AIBS would of course raise considerably the costs of *TRANSACTIONS* and force another increase in dues.

The Michigan State College Press and the University of California Press offered to assist the Society in finding an experienced editor. The University of Wisconsin Press was interested only as a publisher which would include those editorial services that are common and normal to a technical book publisher. It could not provide the technical editorial services. Manuscripts would have to be delivered in a form satisfactory for publication.

The University of Nebraska Press and the University of North Carolina Press are interested in contracting for the publication of *TRANSACTIONS* but here again neither has available an editor with a good understanding of fishery problems. The latter suggested that it might be possible to collaborate with the North Carolina Institute of Fisheries

Research. Both of these presses submitted a series of questions which should be answered if the Executive Committee or the Society decides to let out a contract for publication.

It is our understanding that the problem that confronts the Society is one involving technical editorial work, i. e., work that involves judgment of scientific values, accuracy and consistency of materials, etc.—not merely the correction of language or revision of sentences, marking manuscripts for the printer, etc. Such technical work requires an editor with a good understanding of fishery problems. None of the University presses contacted or the AIBS can furnish such a person. (The Society has no difficulty in getting the purely business services performed gratis by members.)

Neither can a solution be found in cooperating with the American Society of Ichthyologists and Herpetologists, nor presumably with the Wildlife Society. Both of these organizations are confronted with the same problem that face our Society. Technical editing is done gratis for both societies by members. These two societies together with our Society and the American Society of Limnology and Oceanography (when it publishes a journal) might some day be able to employ a full time editor who is fully qualified but not as long as members are willing to perform gratis the editorial, secretarial, and other business services of the society.

Inasmuch as prospects to obtain the required technical editorial services outside the Society are slim, it is recommended that the American Fisheries Society continue its present editorial and publication policy. The present two co-editors are doing a splendid job and are willing to continue this work without compensation. They are carrying the brunt of the drudgery of editing. If the other five members of the Editorial Committee would also do a careful and conscientious job and do it promptly, there would seem to be no reason why the Society's editorial work could not be done well at practically no cost. It is also recommended that one member of the Board be designated as chairman or editor-in-chief so that the final responsibility of the Editorial Committee can be centered in one person. The two co-editors might then be designated as assistant or associate editors.

It may also be pointed out that under the new policy that permits acceptance of manuscripts at any time the work load will be better distributed throughout the year and made lighter if procrastination is avoided by all parties concerned.

COMMITTEE ON CHANGE IN TIME AND PLACE OF MEETINGS

SAM A. PARR

This Committee was appointed by the President of the Society to consider the advisability of changing the time and place of the annual meeting of the American Fisheries Society to coincide with those of the North American Wildlife Conference.

The proposal which the Committee considered is as follows:

(1) The annual meeting of the American Fisheries Society, which is customarily held in the fall in conjunction with the meeting of the International Association of Game, Fish and Conservation Commissioners, would be moved to the week of the North American Wildlife Conference.

(2) The International Association of Game, Fish and Conservation Commissioners would likewise change its time and place of meeting to that of the North American Wildlife Conference.

(3) Should the change be accepted by the Society:

(a) The technical sessions of the North American Wildlife Conference pertaining to fish and fisheries would be planned and conducted by the American Fisheries Society.

(b) The program committee of the American Fisheries Society would cooperate with the officials of the Wildlife Management Institute and the Wildlife Society in planning and conducting the general sessions of the North American Wildlife Conference.

(c) The American Fisheries Society would conduct an independent business session and would have the opportunity to have a separate banquet, if such were deemed desirable, as well as have the opportunity to join in the banquet of the North American Wildlife Conference.

(d) The usual 3-day meeting of the American Fisheries Society would be continued with two half-days devoted to general sessions in cooperation with the North American Wildlife Conference; two half-days devoted to technical sessions; with one evening for a business meeting; one evening for the annual banquet of the Society; a third evening for the banquet of the North American Wildlife Conference; and the third day for field trips or other affairs which might be arranged at the pleasure of the program committee or the committee on local arrangements.

FACTORS FAVORING A CHANGE

(1) The consummation of the organization of regional divisions covering most of the United States and Canada and the annual meetings of these regional divisions has provided a logical means of handling matters which are of less than national or international importance. To maintain a strong central organization, the Society must stage an annual meeting which is characterized by its devotion to matters which are of widespread national and international importance. The proposed change is considered to be a means of strengthening the parent society through improvement in program and through a clear definition of spheres of responsibility between the divisions and the parent society.

(2) A fall meeting date frequently imposes hardships on administrators

and technical personnel who are conducting activities which have not yet been completed by late September, the customary time of meeting. University personnel frequently find a conflict between the late September meeting and the beginning of a new school term. An early spring meeting, on the contrary, would permit all groups to attend at a time when field operations are at a minimum and thus would cause less disruption in activities. Further, a spring meeting would permit the reporting of research findings at an earlier date than is possible with an early fall meeting.

(3) Because of the general attendance of several groups with related interests at the North American Wildlife Conference, fishery workers would have a greater opportunity not only for contacts with workers in their own fields, but also with those in other fields. Eventually, this would lead to a unification of ideas and efforts in the conservation field and hence would result in a stronger national and international conservation effort.

(4) Finally, there is a widespread feeling that the number of meetings which conservation workers are expected to attend has become unduly large in the period since the war, and that a reduction in the time devoted to meeting attendance would be a highly desired end in itself.

FACTORS UNFAVORABLE TO A CHANGE

(1) It has been suggested that the proposed change would result in the absorption of the American Fisheries Society with its ultimate dissolution and disappearance from the international conservation scene. It is feared that the Society would lose its identity.

(2) Attendance by subordinate personnel at the expense of the employing agencies or institutions would be reduced because the top administrators would utilize all of the travel funds available.

(3) A change in publication policies of the Society would be required because of the duplication which would result from Society publication of a separate *TRANSACTIONS* duplicating a part of the report covering the entire North American Wildlife Conference as published by the Wildlife Management Institute.

(4) Conflict with certain legislatures is likely to occur, with a resultant reduction in attendance by administrative personnel.

(5) The meeting would become unwieldy because of the size, with the result that an important value of present meetings would be lost.

CONCLUSIONS

After a thorough consideration of the possibility of a change in customary meeting arrangements in accordance with the proposal outlined above, your Committee has reached the conclusion that it would be unwise to attempt to change at the present time.

We do not believe it wise to sever our strong ties with the International Association of Game, Fish and Conservation Commissioners, and that group, after a study similar to this one, did not take action leading toward a change in meeting place.

We believe that the suggestion for a change of meeting is extremely controversial and capable of fostering ill feeling within the Society of far greater detriment than any assumed advantage which might accrue.

Therefore, your Committee recommends that no further action be taken by the Society at this time leading toward a change in the customary meeting time and place.

COMMITTEE ON WATER POLLUTION

WILLIS M. VAN HORN

The Committee on Water Pollution has to report that it has been unable to carry out completely all the duties with which it was charged by resolution of the Society. As a partial excuse of this, I would like to point out that the problem of water pollution is a grave problem with extensive ramifications and any constructive approach will require time and effort, not only on the part of the Committee but on the part of many individual members of this Society on whom such a committee might call for assistance. It is our belief that resolutions decrying the encroachment of pollution, or calling on various enforcement agencies to halt or clean up present pollution of waters would not be a valuable or significant contribution by this Society.

Several methods of approach have been suggested:

1. To urge a survey of pollution by freshwater fishery people in all states of the United States and the Provinces of Canada, pinpointing with figures each polluted area; and the integration of such data by the Society. This would be a matter of defining the present status of pollution.

2. Accumulation and possibly the publication of information and data on various local treatment methods now effectively in use, with particular reference to their effectiveness in improving aquatic habitat. This would provide background information valuable to members of the Society in meeting their particular problems and would primarily involve a study of what is being done on the American continent in a remedial way.

3. Preparation of an inventory of current research projects and other closely related activities having to do with the effects of water pollution on fish and fisheries. The publication of such an inventory could be useful to field workers of this Society and might measurably assist in the more rapid solution of local pollution problems.

The first could be considered as providing a continuous inventory of pollution on this continent, while the second and third involve the Society

becoming a clearing house of sources of information on pollution research and applied methods of treatment.

It is obvious that each of these proposals involves an undertaking of considerable magnitude. On the other hand the problem itself is of even greater magnitude and its solution will not be obtained by half-hearted measures.

It is the feeling of the members of this committee that it would be to the interest of this Society to continue the study of this problem through a committee empowered to make decision on what course of action should be taken by the Committee, and to call on individual members for assistance in carrying such a course of action to a successful conclusion.

ELECTION OF HONORARY MEMBER

Upon submittal of a petition bearing the names of 10 members in good standing, the following was elected by unanimous vote to honorary life membership in the Society:

Howard K. Balch, Milwaukee, Wisconsin

REPORTS OF SESSIONAL COMMITTEES

COMMITTEE ON TIME AND PLACE

LOUIS A. KRUMHOLZ

The Committee on Time and Place met with the corresponding committee of the International Association of Game, Fish, and Conservation Commissioners. Acceptance was recommended of the invitation issued by the State of Washington. Later, at a meeting of the executive committees of the two societies, it was agreed that the 1954 meeting of the American Fisheries Society shall be held in Seattle, Washington, September 13-15, and the meeting of the International Association of Game, Fish, and Conservation Commissioners September 15-17.

AUDITING COMMITTEE

CLARK HUBBS

The Auditing Committee wishes to report that they have examined the books of the American Fisheries Society for the fiscal year 1952-53 and has found them to be in order. An audit covering the five years which Mr. Sprecher was Secretary-Treasurer made by a certified public accountant, Mr. John L. Okey, was examined and found in order.

The Society is indebted to Mr. Sprecher and his associates in the Wisconsin Conservation Department for the splendid services rendered. The committee is especially impressed by the amount of work which has been donated to the Society. Only a small percentage has been paid by the Society, even though the duties entailed much overtime work.

The Committee wishes to compliment the Secretary-Treasurer for the excellent condition of the books and accounts. He has prepared a detailed schedule of duties which will be of great value to following Secretary-Treasurers.

Especial appreciation is expressed to Miss Ann Zweck for her splendid work and sacrifices in behalf of the Society.

RESOLUTIONS COMMITTEE

STILLMAN WRIGHT

1. North American Fish Policy

WHEREAS, Fifteen years have elapsed since the publication of the North American Fish Policy by the American Fisheries Society, and

WHEREAS, In the intervening years many notable advances have been made in the fields of fish management and research, and

WHEREAS, The recognition of the progress of the past fifteen years inherent in a rewritten policy would be of great value to administrators and technicians as a guide to action and as a means of public enlightenment,

NOW THEREFORE BE IT RESOLVED, That the President appoint a special committee consisting of not more than five individuals to prepare a North American Fish Policy which will reflect present-day understanding of fishery problems, and

BE IT FURTHER RESOLVED, That, upon its adoption, the Society publish a popular version of this policy for free distribution to members.

2. Utilization of Domestic Fishery Resources

WHEREAS, The fishery resources of this country and of the high seas represent a wealth of recreation, nutrition, and employment, and

WHEREAS, The efficient handling, orderly marketing, and balanced consumption of the products of the fishery resources promote wise utilization, which effectively supplements conservation brought about by proper management of the resources in the water, and

WHEREAS, Dependence upon the domestic and high-seas fishery is growing as the domestic population increases and the agricultural facilities approach the point where further physical expansion is not practicable, and

WHEREAS, The Honorable Leverett Saltonstall, United States Senator from the Commonwealth of Massachusetts, has introduced Senate 1731 for the consideration of the 83rd Congress, which bill would authorize one million dollars annually for the Secretary of the Interior to promote the free flow of domestically produced fishery products in commerce by establishing a fishery educational service and research programs in fishery technology and related fields, and

WHEREAS, These activities will be financed by transfer of funds from duties already levied on imported fishery products,

NOW THEREFORE BE IT RESOLVED, That the American Fisheries Society at its eighty-third meeting at Milwaukee, Wisconsin, on September 18, 1953, urge the 83rd Congress to enact Senate 1731 into law, and

BE IT FURTHER RESOLVED, That the Secretary-Treasurer of the Society be directed to forward copies of this resolution to the President of the United States, the Chairman of the Senate Interstate and Foreign Commerce Committee, the Chairman of the House Merchant Marine, and Fisheries Committee, the Secretary of the Interior, and to the ranking majority and minority members of the House and Senate.

3. Survey of Fishery Activities

WHEREAS, This Society last year adopted a resolution urging the U. S. Fish and Wildlife Service to undertake a survey of current fish research and management projects, and

WHEREAS, The Fish and Wildlife Service accepted the responsibility of conducting the survey, and has published the results, and

WHEREAS, The survey has been of material benefit to individuals and agencies concerned with fish conservation,

NOW THEREFORE BE IT RESOLVED, That the Society request the Fish and Wildlife Service to conduct a similar survey in 1954 and annually thereafter.

4. Water Pollution

WHEREAS, The special committee on water pollution has reported that the committee was unable to carry out fully the instructions given to it by resolution of this society last year, because of the magnitude of the water pollution problem, and

WHEREAS, The committee has presented several possible courses of action for consideration,

NOW THEREFORE BE IT RESOLVED, That the President appoint a committee on water pollution to consider the recommendations of this year's committee and other possible courses of action toward the end of developing recommendations for action by the Society in support of pollution abatement programs, and to report its findings and recommendations at the next meeting of the Society.

5. Thanks to the Librarian

WHEREAS, William C. Beckman has served the Society ably as Librarian during the past five-year period, and

WHEREAS, His aggressive policy concerning disposition of surplus stocks of the Transactions resulted in notable improvement in this respect, and

WHEREAS, Circumstances make it impossible for him to continue to carry out the duties of the office,

NOW THEREFORE BE IT RESOLVED, That the Society express its profound thanks to Dr. Beckman for his unique contribution to the affairs of the Society.

6. Thanks for Official Assistance

WHEREAS, The Wisconsin Conservation Commission and Department has assisted the Society greatly for the present meeting and during the past several years by providing personnel and facilities for carrying out the functions of the office of the Secretary-Treasurer, and

WHEREAS, George E. Sprecher, Assistant Director of the Department, during the past five years, has served as Secretary-Treasurer so ably and effectively that the affairs of the Society have undergone outstanding rehabilitation and development, and

WHEREAS, Ann Zweck during the past five years has assisted Secretary-Treasurer Sprecher ably and beyond the call of duty,

NOW THEREFORE BE IT RESOLVED, That the Society express its profound thanks to the Wisconsin Conservation Commission and Department, to George E. Sprecher, and to Ann Zweck.

7. Thanks to Program Committee

WHEREAS, The Eighty-third Meeting of the Society has been outstandingly successful, and

WHEREAS, The members and guests have had available unusual facilities for enjoyment of the sessions and recreational periods,

NOW THEREFORE BE IT RESOLVED, That the American Fisheries Society express its appreciation and gratitude to the Program Committee, and, through its Chairman, Edward Schneberger, to the State of Wisconsin, to the City of Milwaukee, and to the several organizations and individuals who combined resources to make this meeting a success, and

BE IT FURTHER RESOLVED, That special thanks be given to Matt Patterson, practitioner of fishery conservation and development in Wisconsin during the past half century, for his able supervision of the Great Lakes Fish Boil held at the Nevin State Fish Hatchery Grounds on September 16, 1953.

NOMINATING COMMITTEE

SHELBY D. GERKING

The Nominating Committee of the American Fisheries Society was selected by President Hile and notified of its appointment on December 8, 1952, by Secretary-Treasurer Sprecher. The Committee was formed in advance of the Annual Meeting so that the members considered for nomination could be contacted to find whether or not they wished to serve the Society. Members of this committee are George Butler, Minor Clark, Clarence Pautzke, Gordon Trembley, and Shelby Gerking, Chairman.

The Committee began work soon after appointment by examining three traditions which have been followed in the selection of officers and chairmen of standing committees during past years. It has been traditional to rotate the presidency (and therefore the first and second vice-presidencies) from a Canadian member, to a state official, to a federal official. The Committee feels that this rotation is an antiquated method of selection. Several classes of men such as those in colleges and universities, and leaders of private enterprise, are thereby excluded from the presidency. The traditional rotation places additional restrictions upon the selection of officers beyond the statement and intent of the Constitution. The Constitution states (Article III, paragraph 2) that, "Only members in good standing who have been in attendance at one of the two regular meetings preceding their nomination or election shall be eligible for such nomination or election to one of the offices named in paragraph 1." This can only be interpreted to mean that *all* members in good standing who meet the above qualifications are eligible for nomination or election to the five offices mentioned in paragraph 1. In addition, the Committee also feels that the traditional rotation does not fairly represent the distribution of membership in the Society. There are 156 active members in federal agen-

cies, 91 are Canadians, and 1,125 are state employees, college and university personnel, and representatives of private organizations of various kinds.

There has been a traditional selection of standing committee chairmen from the membership of that committee during the previous year. The Nominating Committee feels that this tradition does not always serve the best interests of the Society.

The third tradition has been the ascendancy of the Second Vice-President to the presidency through the office of First Vice-President. No such regular progression is expressly stated in the Constitution but the Nominating Committee feels that the intent of the Constitution would be violated if this progression were not followed.

The Committee has the honor to submit the following slate:

OFFICERS

<i>President</i>	Fred A. Thompson, New Mexico
<i>First Vice-President</i>	Andrew L. Pritchard, Ontario
<i>Second Vice-President</i>	George E. Sprecher, Wisconsin
<i>Secretary-Treasurer</i>	Lee S. Roach, Ohio
<i>Librarian</i>	Howard A. Tanner, Colorado

COMMITTEE ON INTERNATIONAL RELATIONS

Lauren R. Donaldson, Washington, *Chairman*
 Gordon Gunter, Texas
 Robert W. Hiatt, Hawaii
 William R. Martin, New Brunswick
 Edward S. Marvich, Alaska
 Gerry Wade, Maine
 Stillman Wright, District of Columbia

COMMITTEE ON NATIONAL-STATE RELATIONS

Michael Hudoba, District of Columbia, *Chairman*
 C. J. D. Brown, Montana
 Alexander J. Calhoun, California
 Daniel H. Janzen, Minnesota
 Spencer H. Smith, Mississippi

COMMITTEE ON HYDROBIOLOGY AND FISH CULTURE

Robert S. Campbell, Missouri, *Chairman*
 Glenn Gentry, Tennessee
 Frank F. Hooper, Michigan
 William A. Kennedy, Manitoba
 Clifford Millenbach, Washington
 Arthur M. Phillips, Jr., New York
 Richard A. Wagner, Arizona

COMMITTEE ON COMMERCIAL FISHERIES

A. H. MacDonald, Saskatchewan, *Chairman*
 Leonard S. Joeris, Michigan
 Lawrence F. Miller, Alabama
 Duane H. Omstead, Ontario
 Robert W. Schoning, Oregon
 Albert L. Tester, Hawaii
 R. V. Truitt, Maryland

COMMITTEE ON NAMES OF FISHES

Reeve M. Bailey, Michigan, *Chairman*
 Ernest A. Lachner, District of Columbia
 Edward C. Raney, New York
 William E. Ricker, British Columbia
 William B. Scott, Ontario
 Royal D. Suttikus, Louisiana
 Loren P. Woods, Illinois

PRESIDENT HILE: Before I can call for action on the report of this Committee I must give to the members in attendance the privilege of making any additional nominations for officers or committee memberships from the floor. All such officers are subject to the constitutional provisions concerning eligibility. Are there any additional nominations?

MR. DEQUINE: Mr. President, last year some of us protested the system of providing only one name for each of the various offices. We thought a protest might do some good, and I am very happy to see the statement of the Nominating Committee relative to that question and to certain other traditions, but I fail to see where they have implemented their stated policy by any act. I would like to ask for information. Are you calling for nominations for any of the offices or are you taking them up one at a time?

PRESIDENT HILE: If you wish we can go through the offices in order.

MR. GERKING: As a point of correction—in the Committee Report I did not mention the policy of nominating two men for office. I knew an amendment to the By-laws in this matter had been proposed, and I did not know whether it would pass. The Committee could hardly anticipate the action of the Society on this particular matter. We are sympathetic to that viewpoint, however.

MR. DEQUINE: In view of the fact that the Committee took no action as a result of our protest I still wish to protest against the practice of submitting only one name for each of the offices. I do not plan at this time to make any additional nominations, but I do want to get this protest again in the record and advise that another attempt will be made next year, through By-law amendment, to correct what I think is an unfair and unwise system of electing officers.

PRESIDENT HILE: I am glad to see that attitude. I think protestations in themselves do nothing. Any member can circularize for a constitutional amendment and bring it to a vote. If his proposition loses he can try it another time. That's a proper way to operate a society. Every member has a vote and any can start a petition for the amendment of the Constitution. I think all members should feel free to ask for changes, and should also be willing to accept the decision of the majority at the meeting. Now are there any further nominations for President? [No response.] Are there any further nominations for First Vice-President? [No response.] Are there any further nominations for Second Vice-President? [No response.] Are there any further nominations for Secretary-Treasurer?

MR. CARLANDER: Mr. President, I wish to nominate Everett B. Speaker for Secretary-Treasurer. I understand he is willing to serve.

MR. GERKING: I move that the slate of officers proposed, with the exception of Secretary-Treasurer, be accepted as read. [The motion was seconded and carried.]

PRESIDENT HILE: The committees and officers as given, with the exception of Secretary-Treasurer, have been elected. We shall now ballot for Secretary-Treasurer. The members are reminded that only those who are in good standing have the privilege of voting. Any member who suspects the standing of another is entitled to protest. We are still operating under the two-thirds majority rule. For that situation I offer the organization my abject apology. In drawing Amendment No. 4, rejected earlier today, I should not have combined the issues of the general vote and the majority required. I did, and so we lost a good opportunity to change the requirement for election to a simple majority. If there is no objection from the floor I shall ask the members of the Nominating Committee to assume responsibility as tally clerks. [Ballot vote is taken.]

PRESIDENT HILE: Results of the tally show 39 votes for Mr. Roach and 68 for Mr. Speaker. Neither candidate obtained a two-thirds majority. We will now hear further nominations preparatory to a second ballot.

MR. GERKING: Mr. President, the Nominating Committee wishes to present the name of Lee S. Roach for Secretary-Treasurer.

MR. GOTTSCHALK: I wish to nominate Everett B. Speaker. [A motion was made and passed closing the nominations.]

PRESIDENT HILE: The result of the second ballot is: Roach, 27; Speaker, 81. Mr. Speaker is elected. [Applause.]

MR. ROACH: Mr. President, may I offer a motion that the Secretary cast an unanimous ballot for Mr. Speaker for Secretary-Treasurer? [Motion seconded and carried.]

CONCLUDING BUSINESS

PRESIDENT HILE: Now that the elections have been completed I should like to call upon our distinguished service honorary members and past presidents, Charles Hayford and Dr. John Van Oosten, to escort Fred Thompson to the Chair; they may give him advice and condolences en route.

PRESIDENT-ELECT THOMPSON: Gentlemen, I can hardly express myself upon your vote of confidence in me, but I want to assure you that I will put every ounce of effort that I have into furtherance of the Society.

At this time I want to endear myself to all of the members present here by saying one thing: I am not going to make a speech. Thank you so much. [Applause.]

PRESIDENT THOMPSON: I now call for any new business that you wish to bring before the group.

MR. MEEHEAN: Last winter there came over my desk some notices with regard to the importation of fish eggs from foreign countries. I don't know how many of you know it but there have been some rather serious disease problems in various parts of the country. Many of those can be transmitted by being carried on eggs and other equipment from hatcheries that are contaminated. We in the Fish and Wildlife Service have issued instructions that all eggs we get are to be sterilized as soon as they come into the hatchery. We have had one instance this year where the superintendent failed to sterilize the eggs and the fish contracted diseases new to the hatchery.

Another closely related problem is the importation of various species of fish for stocking purposes.

Recently we have been getting a lot of demands for information on *Tilapia*. I have had occasion to visit Asia and have seen the rearing methods, and *Tilapia* has no desirable qualities over and above some of our own sunfishes. Then we have various aquarium species. I would like to have some discussion as to the desirability of getting legislation either requiring eggs to be sterilized as they come into the country or the fish to be quarantined the same as plants and other animals. We have gone into the matter at considerable length. Dr. Snieszko has spent a lot of time on it consulting with the people on his disease panel. They think it is feasible but we do not want to offer any action without some expression on the part of the people in the states that are involved, so I would like to bring that matter up for a discussion. We have a virus disease on the West Coast that has wiped out hatcheries full of sockeye salmon. The virus can be transmitted in the scale instead of the egg and we've had requests from Japan to get some of those sockeye salmon eggs for starting a stock in that country but we had to turn them down because we did not want to ship that disease into new territory. The problem is a serious one.

PRESIDENT THOMPSON: What do you suggest?

MR. MEEHEAN: I suggest that, if it is the desire of the group here, we pass a resolution to have the President appoint a committee to go into the matter thoroughly, probably with some discussion with commercial dealers, state conservation departments, and others. I so move.

MR. DEQUINE: I would like to second Dr. Meehan's motion. We in Florida certainly would be very happy to work with any committee or to help in any way to implement this suggestion.

PRESIDENT THOMPSON: It has been moved and seconded that the president appoint a committee to investigate the condition of importation of fish eggs and fish into the United States. [Motion carried.]

MR. CORNELL: Yesterday afternoon at the business meeting there was demonstrated some evidence of concern over our method of balloting and the principles involved in the election of the officers of the Society. Possibly in the heat of discussion we overlooked fundamental or practical principles that require consideration. At

this time I wish to make a motion that the President appoint a committee to consider the method of balloting to be pursued by the American Fisheries Society, that committee to report at the next annual meeting.

MR. SPRECHER: I am entirely in accord with Mr. Cornell's motion and want to second it. I think it is the proper approach to this constitutional problem.

PRESIDENT THOMPSON: It has been moved and seconded that a committee be named to study the balloting procedure of the American Fisheries Society and to report at the next annual meeting. [Motion carried.]

MR. VAN OOSTEN: Before we adjourn I would like to propose that we give a rising vote of thanks to Dr. Hile for the wonderful job he did as President of the Society in the past year and for the excellent manner in which he conducted the meeting. [Standing applause.]

PRESIDENT THOMPSON: If there is no further business I will entertain a motion for adjournment. [Motion for adjournment made and carried.]

PRESIDENT THOMPSON: I hereby declare the Eighty-third Annual Meeting of the American Fisheries Society adjourned. [Adjourned at 4:30 p.m.]

Appendices

CONSTITUTION OF THE AMERICAN FISHERIES SOCIETY

(Revised 1953)

ARTICLE I

NAME, OBJECTIVES AND PURPOSES

1. The name of the organization shall be the AMERICAN FISHERIES SOCIETY, hereinafter referred to as the Society.

2. The objectives and purposes of the Society shall be:

(a) To promote the conservation, development and wise utilization of the fisheries, both recreational and commercial.

(b) To promote and advance the development and application of all branches of fishery science and practice, including aquatic biology, engineering, economics, fish culture, limnology, oceanography and technology.

(c) To gather and disseminate technical and other information on fishes, fishing, fisheries, and all phases of fishery science and practice.

(d) To hold meetings for the presentation, exchange, and discussion of information, findings and experience on all subjects and techniques related to fishes, fishing, fisheries, and all phases of fishery science and practice.

(e) By such other means as may be appropriate, to unite and encourage those interested in fishes, fishing, fisheries, and all other phases of fishery science and practice.

ARTICLE II

MEMBERSHIP AND ELECTION OF MEMBERS

1. The membership of the Society shall be of the following classes:

(a) *Active Member*: Any person interested in the Society and in the furtherance of its purposes and objectives is eligible for election as an Active Member.

(b) *Life Member*: Any duly-elected active member, upon payment of the fee for life membership as specified in the By-laws, may retain his status as an active member throughout the remainder of his life and shall be exempt from any further payment of dues.

(c) *Sustaining Member*: Individuals, any sporting or fishing club, any society, corporation or other organization is eligible for election as a sustaining member.

(d) *Library Member*: Any technical, public, private, or other library may become a library member.

(e) *Official Member*: Any Federal, State, Provincial, or Territorial department or agency of the United States of America, Government of Canada, United Mexican States, or any other American Republic is eligible for election as an official member.

(f) *Patron*: Any person, society, club, firm, corporation, or other organization is eligible to become a patron.

(g) *Honorary Member*: Honorary members shall be of two classes, *ex officio* and *distinguished service*. The President of the United States of America, the Governor-General of the Government of Canada, the President of the United Mexican States, the Governors of the States and Territories of the United States

of America, the Lieutenant-Governors of the Provinces of Canada, the Secretary of the Interior of the United States of America, the Minister of Fisheries of Canada, and the Secretary of the Navy of Mexico shall be Honorary Members *ex officio*. Any other person of note, by reason of his professional or other attainments, outstanding service to the Society, or his official position, shall be eligible for election as a *distinguished service* honorary member.

2. Nominations for active membership, sustaining membership, library membership, official membership, and patron shall be submitted to the Secretary-Treasurer with the endorsement of at least one active member of the Society. Except as provided in paragraph 3, such nominations shall be presented to the members present at any regular or special meeting and shall be considered elected if they receive an affirmative vote of a majority of the members present at such meeting. Nominations for honorary membership shall be submitted with the endorsement of at least ten active members of the Society in good standing, and the unanimous vote of all members present at any regular or special meeting shall be required for election.

3. The Executive Committee, established pursuant to Article III, is authorized to consider and vote upon nominations for all classes of membership, except nominations for honorary membership, during the intervals between meetings. When so authorized by the Executive Committee, the President of the Society and the Secretary-Treasurer, acting jointly, may pass upon such nominations during the said intervals.

4. The names of elected members shall not be added to the membership rolls of the Society until they have paid such dues, fees or assessments for a period of at least one year as are enumerated in the By-laws adopted pursuant to Article V.

5. As used in this Constitution, and in the By-laws adopted pursuant to Article V, the term member "in good standing" means any active member, sustaining member, library member, or official member, whose dues are not more than one year in arrears, and any life member, honorary member, or patron; provided that only active members in good standing, life members, and distinguished service honorary members shall be entitled to vote.

ARTICLE III

OFFICERS AND EXECUTIVE COMMITTEE

1. The officers of the Society shall be a President, a First Vice-President, a Second Vice-President, a Secretary-Treasurer, and a Librarian.

2. Only active members in good standing, life members, and distinguished service honorary members who have been in attendance at one of the two regular meetings preceding their nomination or election shall be eligible for such nomination or election to one of the offices named in Paragraph 1; *except that* the Librarian shall be exempt from the requirement of attendance at one of the two previous meetings. Members who accept nomination and are elected to hold one of the offices of the Society, are bound to perform their duties to the best of their ability and to advance the purposes and objectives of the Society.

3. Officers shall be elected and serve for a period of one year, or until the next regular or annual meeting, and shall (with the exception of the Secretary-Treasurer and the Librarian) be ineligible for reelection to the same office for a period of one year after the expiration of their terms of office.

4. The officers named in paragraph 1, the President of the preceding year, the chairman of any regional division established pursuant to the provisions of Article VI, and the chairman of any standing committees established in accordance with the By-laws adopted in accordance with Article V, shall constitute the Executive Committee. The Executive Committee is authorized to decide the policies of the Society, and to transact such business of the Society as may be necessary between regular or annual meetings.

5. In the event of the cancellation of a regular or annual meeting, the officers enumerated in paragraph 1 of this Article and the members of any standing or special committees established in accordance with the By-laws adopted in pursuance of Article V shall continue to serve until such time as a regular meeting can be scheduled at which new officers shall be elected and new committee members elected or appointed.

ARTICLE IV

MEETINGS AND VOTING

1. The Society shall meet once a year at a time and place to be decided upon by the membership at the preceding regular or annual meeting, or, in default of such decision by the membership, by the Executive Committee. Special meetings may be called by the President with the approval of the Executive Committee.

2. In the event of an emergency, the Executive Committee shall have the power to cancel a regular or annual meeting, or to change the place of an annual meeting; and in the event of such cancellation the Executive Committee shall have the power to schedule the next regular meeting.

3. A quorum at any meeting for the transaction of official business shall consist of at least twenty-five active members in good standing.

4. Decisions at meetings, including election of members, shall be by a majority of those present at any meeting; *except that* for election of officers and members of committees, and for a motion for amendment of By-laws adopted pursuant to Article V, a two-thirds majority shall be required; and *excepted further*, a unanimous vote shall be required for the election of honorary members.

ARTICLE V

AUTHORIZATION FOR THE ADOPTION OF BY-LAWS

1. The Society is authorized to adopt and to amend subsequently as may be required, in accordance with the provisions of paragraph 4 of

Article IV, such By-laws as may be necessary for the conduct of the business of the Society.

2. By-laws adopted pursuant to the provisions of this Article must include, but shall not be limited to, the following:

(a) Set forth the amount of annual dues and special fees or assessments for the various classes of membership of the Society, and deal with other matters pertaining to the finances of the Society.

(b) Prescribe the duties of officers of the Society.

(c) Provide for the establishment of and specify the terms of reference or duties and method of selection (by Presidential appointment or by election) of such standing committees, other than the Executive Committee, established in accordance with Paragraph 4 of Article III, and such sessional committees as may be necessary for the conduct of the business of the Society and the furtherance of its purposes and objectives. For the purposes of this subparagraph, (1) a standing committee is defined as one which is established permanently in the By-laws as a part of the basic organization of the Society; and (2) a sessional committee is defined as one constituted for the purpose of undertaking specific tasks at or in preparation for a regular or special meeting of the Society and is discharged upon submission of its report or completion of its business.

(d) Notwithstanding the provisions of subparagraph (c) of this paragraph, the President may appoint, or the Society, by adoption of an appropriate resolution, may direct the President to appoint special committees to undertake special assignments; and such authorization or appointments shall not require amendment of the By-laws, and such committees shall automatically be abolished on completion of their assignments or on the date of the next regular meeting, whichever occurs first.

(e) Provide authorization for such official publications of the Society as may be necessary in the furtherance of its purposes and objectives.

(f) Provide for the establishment and maintenance of any regional divisions of the Society established pursuant to the provisions of Article VI.

ARTICLE VI

REGIONAL DIVISIONS

1. A regional division of the Society may be established by the favorable action of the Society, pursuant to paragraph 4 of Article IV, upon a petition presented to it at any regular meeting by not less than twenty-five members of the Society in good standing resident in a particular geographic region.

2. Such regional division or divisions shall be organized in accordance with pertinent provisions of the By-laws adopted pursuant to Article V.

3. Each such regional division may adopt and amend from time to time its own By-laws, which shall conform to the provisions of this Constitution and By-laws of the Society adopted pursuant to Article V. The By-laws of regional divisions, after adoption and each amendment, shall be reviewed by the Executive Committee of the Society to insure conformance with the Constitution and By-laws of the Society. No By-laws of regional divisions or amendments thereof shall be considered effective until

such review by the Executive Committee of the Society has been completed and the chairman of the regional division has been notified in writing by the Secretary-Treasurer of the Society that such by-laws or amendments thereof are in conformity with the Constitution and By-laws of the Society.

4. Each regional division shall elect its officers, which shall consist of a chairman, vice-chairman and secretary. The chairman of any regional division shall be a member of the Executive Committee of the Society, and in his absence or inability to attend meetings of the Executive Committee the vice-chairman of that regional division may act in his stead. The secretary of any regional division of the Society shall serve as an assistant to the Secretary-Treasurer of the Society and shall carry out his duties in accordance with such procedures as may be determined from time to time by the Secretary-Treasurer of the Society.

5. All members of the Society who reside within a designated region in which a regional division of the Society may be established shall, upon election to membership and payment of dues prescribed in the By-laws, be considered a member both of such regional division and of the Society as a whole. Qualifications for membership in regional divisions shall conform to qualifications for membership in the Society. Regional divisions may elect active and life members only. The other classes of membership set forth in Article IV shall be elected only by the Society.

6. The regional divisions may, with the approval of the Executive Committee of the Society, levy such special fees, in addition to the dues of regular members of the Society, as may be necessary to meet any expenses of the regional divisions which are not properly chargeable to the regular funds of the Society. All regular Society dues shall be paid only to the Secretary-Treasurer of the Society. Any special fees collected by the regional division shall be disbursed by the secretary of the regional division in accordance with the By-laws of such regional division and the authorization of its officers and members.

7. The Executive Committee may allot to any regional division, from time to time, such sums from the treasury of the Society as may be necessary to further through the regional division the purposes and objectives of the Society. Such allotted funds shall be disbursed by the secretary of the regional division in accordance with its By-laws and the decisions of its officers and membership.

ARTICLE VII

AMENDMENT OF CONSTITUTION

1. This Constitution, after adoption in accordance with the provisions of the existing Constitution and By-laws, shall supersede such previously adopted Constitution.

2. The Constitution may be amended upon recommendation of three-fourths of the Executive Committee which shall be circulated in writing of the membership at least 30 days prior to any regular meeting at which a vote is to be taken, and upon approval by a two-thirds majority of the members present at such regular meeting, provided a quorum is present.

3. A petition for amendment of this Constitution signed by not less than 50 members in good standing, irrespective of any action relative thereto taken by the Executive Committee in pursuance of paragraph 2 of this Article, shall be circulated to the membership by the Secretary-Treasurer at least 30 days prior to a regular meeting, and such amendment shall become effective upon approval by a two-thirds majority of the members present at such regular meeting, provided a quorum is present.

BY-LAWS OF THE AMERICAN FISHERIES SOCIETY

Section 1.—
Duties of
the
President The President is responsible for the business and organization of the Society, shall make such appointments as are authorized in the By-laws, and shall exercise such other functions and responsibilities as may be determined from time to time by action of the Society or the Executive Committee. He shall preside at all meetings of the Society, and at all meetings of the Executive Committee, of which he is chairman.

Section 2.—
Duties of
the Vice-
Presidents The First Vice-President shall assume the duties of the President during his absence or in case of his inability to act. The Second Vice-President shall assume the duties of the President during the absence of the President or the First Vice-President or in case of their inability to act. Upon designation by the President, the First Vice-President or the Second Vice-President shall preside at sessions at regular or special meetings.

Section 3.—
Duties of
the
Secretary-
Treasurer The Secretary-Treasurer, in his capacity as Secretary, shall be responsible for maintaining the official records of the Society, shall conduct its official correspondence, promote its membership, and shall make arrangements for regular and special meetings of the Society, and for meetings of the Executive Committee. He shall serve as parliamentary advisor to the President and chairman of committees to insure that the business of the Society is conducted in accordance with the provisions of the Constitution and By-laws.

The Secretary-Treasurer, in his capacity as Treasurer, shall receive and collect all dues, fees, accounts receivable, and other income of the Society, shall have the custody of its funds, and shall pay all accounts payable and other claims

which have been duly authorized and approved. He shall furnish a bond in the sum of \$7,500, on surety, to be approved by the Executive Committee, the premium for such bond to be paid by the Society. The Secretary-Treasurer shall present an annual report to the Society.

**Section 4.—
Duties of
the
Librarian**

The Librarian shall have the custody of the library of the Society, including its archives and printed publications, and shall have charge of the sale of extra copies of its publications. He shall transmit promptly to the Secretary-Treasurer monies received from such sales.

**Section 5.—
Expenses of
Officers**

No elected officer or committee member of the Society shall receive any salary or other compensation for his services. Clerical and other necessary expenses of elected officers and committee members may be defrayed by the Society provided that it has, through action at a regular meeting, or by vote of the Executive Committee in the event of an emergency during the interval between regular meetings, authorized such disbursements in advance.

**Section 6.—
Official
Publications**

The minutes and proceedings of all regular and special meetings of the Society and of any regional division established pursuant to Article VI of the Constitution, together with reports of officers and committees at such meetings, technical papers furnished by members and selected by the Editorial Board for publication, and the official membership list of the Society shall be published in an annual volume which shall be numbered in series with the preceding volumes and shall be entitled: TRANSACTIONS OF THE AMERICAN FISHERIES SOCIETY. Each member of the Society in good standing shall receive one copy of the publications issued; except that publications shall not be distributed to patrons and *ex officio* honorary members..

**Section 7.—
Presentation
and Publica-
tions of Manu-
scripts**

Only members in good standing may present papers, either by reading or by title, at annual meetings of the Society or submit them for publication by the Society; *except* that outstanding non-members invited by the President of the Society, or Secretary-Treasurer with the advice of the President, who present papers at any meeting shall be exempt from this requirement. No member may have listed on the program of any meeting of the Society or any regional division thereof, or present, or have published in any one volume of the TRANSACTIONS, more than two papers; and for purposes of this section joint authorship shall be considered in the same status as sole authorships.

**Section 8.—
Dues of
Members**

The dues of the various classes of members, payable to the Secretary-Treasurer of the Society, shall be as follows:

- (a) Active member, \$4.50 per annum.
- (b) Life member, \$75; payable, if desired, in two consecutive annual installments of \$37.50 each.
- (c) Library member, \$4 per annum.
- (d) Sustaining member, \$10 per annum.
- (e) Official member, \$40 per annum.
- (f) Patron, a single contribution of \$250 or more.
- (g) Honorary member, no dues.

All dues, fees, or other monies due the Society shall be paid in currency of the United States of America, or the equivalent in foreign currency at current rates of exchange in the United States of America.

**Section 9.—
Loss of
Membership**

Any member who fails to pay his dues for a period of more than one year shall be given written notice by the Secretary-Treasurer that his name will be removed from the membership list unless back dues are paid in full within 60 days from the date of such notice. Any member who has forfeited his membership may not be reelected as a member for a period of one year from date of forfeiture of his membership unless he has paid all back dues and has paid dues for one additional year in advance.

**Section 10.—
Committee on
International
Relations**

The Committee on International Relations is a standing committee responsible for keeping the Society informed as to the work of foreign technical agencies, international organizations, meetings, conferences, negotiations, exchange of persons and information, and related international matters of interest to the Society, and shall recommend such action or participation by the Society as may be appropriate in the furtherance of the Society's purposes and objectives. It shall consider problems of legislation and implementation of international agreements relating to the interests, purposes and objectives of the Society. The Committee shall consist of seven members in good standing, who shall be named by the nominating committee and elected by the Society. The Committee shall report to the Society annually concerning its work.

**Section 11.—
Committee
on National-
State
Relations**

The Committee on National-State Relations is a standing committee which shall act as a coordinating and advisory board for the consideration of interstate and National-State fishery problems and programs in the United States of America. It shall also consider problems of administration of fishery

resources, and Federal and State legislation and the implementation thereof in the fields of fishery conservation and management. The Committee shall consist of five members in good standing, at least one and no more than two of which shall be an officer or officers of the United States Government, who shall be named by the nominating committee and elected by the membership. The Committee shall report annually to the Society concerning its work, which report shall include such recommendations for action by the Society as are considered appropriate.

**Section 12.—
Editorial
Board**

The Editorial Board is a standing committee responsible for the editing and publication of the proceedings of meetings, including technical papers and other manuscripts, and for their publication in the name of the Society. The Board shall consist of not fewer than five members in good standing of proven technical and editorial abilities, each of whom shall serve at the discretion of the President. Each President, immediately upon his election shall appoint the members of the Editorial Board, and shall designate the chairman for the coming year. The chairman of the Board shall be known as the Editor; each other member shall be termed Managing Editor, Associate Editor, Assistant to the Editor, . . . or given such other titles as may describe appropriately his functions and duties. The Editor shall assign duties to other members of the Board, and may solicit assistance, from time to time, for temporary periods from other members of the Society. The Board is authorized to establish and issue such standards and instructions to the membership as may facilitate its work. The Board shall report to the Society annually concerning its work.

**Section 13.—
Committee on
Hydrobiology
and Fish
Culture**

The Committee on Hydrobiology and Fish Culture is a standing committee which shall maintain a continuous survey and appraisal of research and applied work in the fields of aquatic biology, physiology, limnology, and oceanography as related to fishery science, fish culture, and fishery management. It shall develop and encourage the standardization and improvement of techniques, procedures, nomenclature, and measurements; and shall consider problems of pollution control. The Committee shall be composed of seven members in good standing who are recognized specialists in various phases of fishery science and practice, and who shall be named by the nominating committee and elected by the membership. The Committee shall report annually to the Society concerning its work, placing emphasis on developments during the past year.

**Section 14.—
Committee
on
Commercial
Fisheries**

The Committee on Commercial Fisheries is a standing committee responsible for promoting and improving fishery techniques and the utilization of fishery resources for food and by-products, for the development and recommendation of standards of quality and sanitation, for the development and recommendation of standardized procedures for the collection and analysis of fishery statistics, and for related activities. The Committee shall be composed of seven members in good standing who are recognized specialists or authorities in fishery economics, technology, or the fishery industries, and who shall be named by the nominating committee and elected by the membership. The Committee shall report annually to the Society concerning its work, placing emphasis on developments during the past year.

**Section 15.—
Committee
on Names
of Fishes**

The Committee on Names of Fishes is a standing committee responsible for the establishment and maintenance of a check list of common and scientific names of fishes, with the objective of achieving uniformity and avoiding confusion in nomenclature. The Librarian shall be custodian of the master check list. The Committee, in the furtherance of its duties, shall coordinate its activities with those of other societies and organizations throughout the world. The Committee shall be composed of seven members named by the nominating committee and elected by the membership, such members to be outstanding specialists in the fields of systematic ichthyology and fishery biology. The Committee shall report to the Society annually concerning its work.

**Section 16.—
Membership
Committee**

The Membership Committee is a standing committee responsible for maintaining and increasing the membership of the Society. The Committee shall take such measures as it deems appropriate and effective to stimulate interest in the Society and to further its purposes and objectives by interesting qualified persons in membership. The committee shall consist of the First Vice-President, who shall be chairman, of the Second Vice-President who shall be vice-chairman, and nine other members in good standing who shall be appointed by the President within 30 days after his election. The Secretary-Treasurer shall be an *ex-officio* member. The Committee shall report to the Society annually concerning its work.

**Section 17.—
Program
Committee**

The Program Committee is a standing committee responsible for arrangement of the program at the regular meetings, consisting of technical sessions for the reading and discussion of original papers, symposia on important topics, and exhibits of interest to the Society. It is the duty of the Committee to insure that the programs at the regular meetings are of high quality and achieve balance among the various fields

of interest and activity of the Society. The Committee may recommend to the President the issuance of invitations to outstanding non-members to present papers or addresses. The Committee shall consist of five members in good standing appointed by the President within 30 days after his election, who shall serve until the close of the next annual meeting.

**Section 18.—
Sessional
Committees**

The President is authorized to appoint, from the members of the Society in good standing, prior to, or at the beginning of each regular meeting, such sessional committees as may be necessary for the conduct of the business of the Society and other authorized activities in conjunction therewith; including the following:

- (a) Nominating Committee of five, which shall name a list of officers and members of Committees that are subject to election by the Society, which shall be presented to the members for action at a regular meeting. It is the duty of the Committee to insure that all persons named shall conform to the qualifications for the various offices and committee memberships set forth in the Constitution and By-laws. The right of any member to nominate a candidate for any office or committee membership from the floor during a regular meeting, or to second such nomination, is expressly reserved.
- (b) Resolutions Committee of five, which shall draft and recommend to the Society for consideration and vote at a regular meeting such resolutions, including amendments of the By-laws, as may be considered prudent and necessary for the furtherance of the purposes and objectives of the Society and for the conduct of its business.
- (c) Auditing Committee of three, which shall examine the accounts of the treasurer and report its findings to the Society, and shall consider the annual budget of the Society prepared by the Secretary-Treasurer with the advice of the Executive Committee, and make recommendations concerning it for the action of the membership.
- (d) Time and Place Committee of five, which shall consider and recommend to the membership for action, the time and place for subsequent regular meetings.
- (e) Publicity Committee of three members, which shall draft, approve, and disseminate appropriate press notices and reports concerning the meetings of the Society and the proceedings thereat as may be appropriate and in furtherance of the purposes and objectives of the Society.

Section 19.— The order of business at regular meetings of the Society shall include, but shall not necessarily be limited to, the following:
Order of Business

1. Call to order by the President.
2. Address of the President on a timely subject of his choice.
3. Roll call of members (or determination that a quorum is present).
4. Action on nominations for membership.
5. Introduction of noteworthy guests and visitors.
6. Appointment of sessional committees by the President:
 - a. Nominating Committee of five.
 - b. Resolutions Committee of five.
 - c. Auditing Committee of three.
 - d. Time and Place Committee of five.
 - e. Publicity Committee of three.
7. Report of the Secretary-Treasurer.
8. Report of the Librarian.
9. Report of the chairmen of regional divisions.
10. Reports of Standing Committees.
11. Reports of Special Committees.
12. Program of papers, symposia, and discussions.
13. Report of the Time and Place Committee.
14. Report of the Auditing Committee.
15. Report of the Resolutions Committee.
16. Report of the Nominating Committee.
17. Election of officers and members of such standing committees as are subject to election by the membership.
18. Installation of newly-elected officers.
19. Other business.
20. Adjournment.

Section 20.—
Northeastern
Division

- (a) In accordance with the provisions of Article VI of the Constitution there is established a Northeastern Division of the American Fisheries Society which consists of members in good standing from the states of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, West Virginia, and the District of

Columbia in the United States of America, and the Provinces of New Brunswick, Newfoundland, Nova Scotia, Ontario, Prince Edward Island, and Quebec of the Dominion of Canada.

- (b) The Chairman of the Northeastern Division shall submit a report of this division to the Society at each regular meeting and the Secretary of the Northeastern Division shall submit a report to the Secretary-Treasurer of the Society at each regular meeting.

Section 21.—
Southern
Division

- (a) In accordance with the provisions of Article VI of the Constitution there is established a Southern Division of the American Fisheries Society which consists of members in good standing from the states of Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and members residing in Cuba, Puerto Rico, the Virgin Islands, and other West Indian Islands.
- (b) The Chairman of the Southern Division shall submit a report of this division to the Society at each regular meeting and the Secretary of the Southern Division shall submit a report to the Secretary-Treasurer of the Society at each regular meeting.

Section 22.—
Western
Division

- (a) In accordance with the provisions of Article VI of the Constitution, there is hereby established a Western Division of the American Fisheries Society, which consists of members in good standing from the states of Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming and the Territories of Alaska and Hawaii of the United States of America; and from the Provinces of Alberta, British Columbia, and Saskatchewan of the Dominion of Canada.
 - (b) The Chairman of the Western Division shall submit a report of this division to the Society at each regular meeting and the Secretary of the Western Division shall submit a report to the Secretary-Treasurer of the Society at each regular meeting.
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INSTRUCTIONS FOR PREPARING MANUSCRIPTS FOR THE TRANSACTIONS OF THE AMERICAN FISHERIES SOCIETY

(REVISED 1954)

Please check each item below before the final typing of your manuscript and help reduce the costs of publication, save your Editorial Board much needless work, and avoid delay in the publication of the *Transactions*.

The following instructions were not drawn up arbitrarily but were condensed from the regulations contained in the best style manuals. Certain instructions may appear unnecessary, but they are nevertheless essential for the proper handling of materials by the printer and the editor.

I. MECHANICAL DETAILS

1. **Manuscript must be typewritten double-spaced**, including titles, headings, legends for tables and illustrations, and literature citations. Write manuscript only in simple upper and lower case. *Do not use all capital letters for any purpose and underscore only where italics are intended.*

2. **Carbon copies or originals made with a worn-out ribbon will not be accepted.** Do not use thin paper; heavy bond is preferred.

3. **Margins** at top, bottom, and both sides must be no less than $1\frac{1}{4}$ inches to allow space for the insertion of directions to the printer and necessary corrections.

4. **Pages must be numbered in consecutive order**, including tables and pages carrying legends to figures. Tables and legends of figures must be inserted near their place of reference in the text.

5. **Illustrations.** Make a separate page of each figure legend and limit the number of figures to those absolutely necessary to clarify or supplement text. Only sharp, glossy photographs can be used. Photostats will not be accepted. All drawings, charts, and diagrams should be prepared in waterproof India ink on high-quality paper or tracing cloth. Graph paper must not be used. No erasures should be made. Shading should be limited to a minimum and when used the lines should be kept open. The curves of graphs should be drawn much bolder than any guide lines or ruling. Lettering should be bold and sufficiently large and spaced apart so that the letters or numbers will not be less than 1 millimeter high or come in contact when reduced. Drawings should be made at least twice the size required for reproduction, and when large should be of proper proportion so that they will not exceed $4\frac{1}{4}$ by $6\frac{1}{2}$ inches (inclusive of legends) when reduced. *All explanatory matter other than the units along each axis of a graph or diagram and those designations needed for clarity should be placed in the legend.* The legend, which should be typewritten on a separate sheet, will be set in type below the figure.

Make proper reference in text to all plates, maps, and charts, and designate all of these, except tables, as figures, numbering them in consecutive order with Arabic, not Roman, numerals.

6. **Footnotes** in text should be numbered consecutively and should be placed immediately after the full line of text in which the reference mark occurs, but do not break a line of text to insert footnote. Separate the footnote from the text by two horizontal lines, one above and one below the note. In each new table footnotes should begin with 1. Do not use asterisks or other symbols to call attention to footnotes to tables.

7. **The title** of the manuscript, together with the author's name, division, or depart-

ment, and post office address, should always appear at the top of the first page of the manuscript as follows, allowing at least *triple space between lines* to permit the insertion of instructions to the printer.

TREATMENT OF DISEASES OF BROOK TROUT

JOHN EDWARD DOE

Department of Conservation, Lansing, Michigan

8. **Underscore** (*italics*) all scientific names of genera and species, both animals and plants, in both text and tables. Do not underscore or use all capital letters for scientific names of a category higher than the genus: Esocidae; *Esox lucius*. *Do not underscore any words unless italics are intended.*

9. **Inspect papers** in the last volume of the *Transactions* if you have questions concerning the arrangement of materials.

II. STYLE

10. **Bibliographic references** in text should give name of author and year of publication in one of the two following forms. "A similar reaction to light was reported by Doe (1932)." "This type of reaction appears to be common (Doe, 1932)." Do not use letters or numbers or footnotes for references. If more than one publication by the same author is given for a year, use the alphabet to designate the correct paper, thus: (Doe, 1932a) or (Doe, 1932b). In the bibliography do not repeat the author's name if reference is made to more than one of his publications, but list his publications in chronological order beginning with the earliest one. In citing a joint publication invert the name of the senior author but not of the co-author or co-authors. *Do not include any reference not mentioned in the text.* List authors in alphabetical sequence. Capitalize the first word and proper names only in the title. Follow the arrangement given below, to be placed at end of paper:

LITERATURE CITED

DOE, JOHN C., J. W. BROWN, and H. W. GREEN

1939. Treatment of diseases of brook trout. *Trans. Am. Fish. Soc.*, Vol. 68 (1938), pp. 450-461.

List only bona fide publications under Literature Cited. Do not list personal communications, typewritten reports, or processed materials given only limited distribution but rather give the appropriate citations in text footnotes at point of reference.

Please check your references carefully as to titles, spelling, capitalization, italics, diacritical marks, abbreviations, etc., against their original sources, after the final typing, and *state beneath your bibliography that you have done so.* Many bibliographic titles published in the *Transactions* have been found to be incomplete and inaccurate. Help us correct this situation.

11. **Tables.** Every table except leader work must have a heading and must be typewritten on a separate page. In preparing tables please make certain that they are not too large to appear on a single printed page and that the arrangement conforms with the format of the *Transactions*. *Improperly prepared tables lead to the return of many manuscripts.* Number tables consecutively with Arabic numerals (1, 2, 3, etc.). Spell all words in tables, including such words as "millimeters," "ounces," and "average" (except months *with date*, in body of table), and capitalize, as a rule, the first word only in headings in the first column or over other columns. Precede all decimal numbers with zero. Use dollar sign only with first number at top of column and under each cross rule.

Item	Number of fish	Percentage of total	Average length (millimeters)	Months	Cost of diet per pound
Brook trout surviving experiment No. 2	23	5.8	65	April-September	\$0.25

12. Capitals. Capitalize words when used as part of a proper name or of an identifying number or letter, or when referring to particular States, Governments, and organized bodies, or when used as proper names. For example: Lake Michigan, State of Michigan, the State, the Province, the Republic, Washtenaw County, Ann Arbor Township, Huron River, Pacific Ocean, North Atlantic, Northern States, Hoover Dam, Pond A, State Fish Farm No. 1, Pisgah National Forest, American Fisheries Society.

Capitalize names of sections of the United States, or of any other country, as Middle West, but use lower case for a term prefixed to any such sections, as eastern North Atlantic States.

Capitalize any term (except page or pages and age group) preceding Roman numerals, as Article I, Chapter II, Sample VI, etc. Also capitalize such terms as Appendix 1 or Appendix A, Experiment 2, Table 4, and Figure 6.

Use lower case for scientific and common names of species. Capitalize scientific names of higher categories.

13. Abbreviations.

(a) Abbreviate the following:

Clock time, if connected with figures—2:30 a.m.

Temperatures, F. (Fahrenheit).

Degrees, whether referring to temperatures, longitude and latitude, or angles, etc.—75°, 75° F., 75° C.

Number, if preceding figures—No. 125; otherwise spell out.

United States, if preceding name of a department or a bureau of a vessel, etc.—

U. S. Department of the Interior, U. S. S. *Indiana*.

Months, in body of tables and footnotes to same when followed by day of month—Apr. 5–Sept. 2 (but April–September).

(b) Do not abbreviate the following:

States, cities, etc.

Months, in text or in headings of tables—April 5–September 2.

Measures and weight, except p.p.m., 6 inches, 20 millimeters, 5 ounces, 1.5 acres, etc.

Percentage, 12 percent, a percentage of 25.5.

14. Numerals. Spell out *isolated* numbers less than 10, but treat alike all numbers in a series of connected groups. For example: The nets contained nine bluegills. The catch included 9 bluegills, 20 smallmouth bass, and 123 pumpkinseeds.

Use figures for enumerations of quantities and measurements, such as dimension, weight, area, volume, distance, clock time, time, money, percentage, degrees, proportion or ratios, ages, dates, page numbers, decimals, and mixed numbers (spell out common fractions if alone but use numeral if part of a hyphenated expression: one-half inch; ½-inch mesh). Examples: \$3.00 per 20 pounds; 5 feet 6 inches; 10 miles; 6 acres; 15 cubic centimeters; 4:30 p.m.; fish died in 1 hour and 20 minutes; 25.5 percent; 75° F.; 1:10,000; fish 2 years 6 months old; 2-year-old fish; June 29, 1936; January 1938; the 20th day of March; 1937–1938; 4.5 p.p.m.; 0.25; 1½ pages; page 215.

Write 8 by 12, not 8 x 12 unless multiplication is indicated. Write 50–50, not “fifty–fifty.”

Do not use two figures when two numbers appear together, unless the first enu-

meration exceeds 100: ten 12-room houses; twenty 6-inch bluegills; 120 6-inch bluegills.

Spell out figures beginning a sentence, but avoid such use of numerals if possible. Spell out both numbers of two related amounts at the beginning of a sentence in such expressions as "Twenty to twenty-five lake trout," but write "Two hundred fifty rock bass and 325 lake trout were shipped."

In expressing large numbers the word *million* (or a similar larger group term) may be spelled out: 20 million, 2¾ billions.

15. Use of hyphen. Many compound words when used as nouns are not hyphenated but require the hyphen when used as adjectives. For example note the following sentences: "This species is adapted to *cold water*." "Ciscoes are *cold-water* fish." Write "fish culture," but "fish-culturist." Check your manuscript carefully for use of hyphen. The words, "subspecies," "upstream" and many other words originally of compound derivation are written without a hyphen.

III. SUBJECT MATTER

16. Condense your paper to the limit and omit all needless verbiage. The manuscript should be simple, clear, concise, accurate, consistent, and complete. *Accuracy* in subject matter, in scientific names, and in bibliography is especially important. **Papers which are too poorly written will be rejected.**

17. Be definite in reference to species. The full common name and the scientific name must be given for each species mentioned. Scientific names may be omitted from the title, if desirable, but must be given at first reference to the species in the text. Once given, scientific names need not be repeated. Follow the Society's official list of names. Do not write "smallmouth," "brook," "rainbow," etc., when you mean "smallmouth bass," "brook trout," "rainbow trout," etc.

18. Things to avoid. Words that do not appear in the dictionary in the sense employed should be avoided. The words "case," "instance," "showed," "found," "gave," and "presented," are greatly overworked in manuscripts.

Avoid the repeated use of *participles* which, as a rule, weaken sentences. In the following illustration note the improvement when the words in parentheses are used: "The principles underlying (that underlie) the production of beef are essentially the same as those involving (that are involved in) the production of bass."

Avoid *split infinitives*. Please check your manuscript for this common error.

Avoid the use of *this* and *these* as substantives. Compare, for example, the following two sentences for effectiveness: "*This* was true in every case." "*The mortality* was high in every pond."

Avoid the use of a long series of nouns and adjectives as modifiers.

Avoid the use of such meaningless section headings as "Data" and "Discussion."

19. Things to remember. Well written papers are the product of careful thought and hard work. Usually they require repeated revisions that incorporate suggestions from discerning and honestly critical associates. Please make these revisions *before* submitting your manuscript.

Good writing is to a large extent a matter of good taste and good manners. Careless presentation and poor organization are rank discourtesy toward the readers.

Careless writing may save time but, once printed, a weak paper stands long as a discredit to its author.

20. Abstract of paper. Give a brief abstract at the beginning of your paper. Do not include a "Summary" at the end of your paper; if "Conclusions" are given make them brief and not a duplication of materials in the abstract.

Prepared by the Editorial Board

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